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ABSTRACT

Written in student performance terms, this curriculum guide on diesel engine repair is divided into the following eight sections: an orientation to the occupational field and instructional prcgram; instruction in operating principles; instruction in engine components; instruction in auxiliary systems; instruction in fuel systems; instruction in electrical systems; instruction in engine performance; and instruction in welding. Each section consists of one or more units of instruction. Each instructional unit includes some or all of the following components: performance objectives, suggested activities for teacher and students, information sheets, assignment sheets, job sheets, visual aids, tests, and answers to the tests. Units are planned for more than one lesson or class period cf instruction. Numerous diagrams supplement the text. (BM)

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DIESEL ENGINE MECHANICS

by
William A. Foutes

Developed by the
Mid-America Vocational Curriculum Consortium, Inc.

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FOREWORD

The Mid-America Vocational Curriculum Consortium (MAVCC) was organized for the purpose of developing instructional materials for twelve member states. Priorities for developing MAVCC materials are determined annually based on the needs as identified by all member states. One of the priorities identified was Diesel Engine Mechanics. This publication is designed to provide the needed instructional material for diesel engine mechanics programs.

The success of this publication is due, in large part, to the capabilities of the personnel who worked with its development. The technical writer has numerous years of industry as well as teaching experience. Assisting him in his efforts were representatives of each of the member states who brought with them technical expertise and the experience related to the classroom and to the trade. To assure that the materials would parallel the industry environment and be accepted as a transportable basic teaching tool, organizations and industry representatives were involved in the developmental phases of the manual. Appreciation is extended to them for their valuable contributions to the manual.

This publication is designed to assist teachers in improving instruction. As these publications are used, it is hoped that the student performance will improve and that students will be better able to assume a role in their chosen occupation, diesel engine repair.

Instructional materials in this publication are written in terms of student performance using measurable objectives. This is an innovative approach to teaching that accents and augments the teaching/learning process. Criterion referenced evaluation instruments are provided for uniform measurement of student progress. In addition to evaluating recall information, teachers are encouraged to evaluate the other areas including process and product as indicated at the end of each instructional unit.

It is the sincere belief of the MAVCC personnel and all those members who served on the committees that this publication will allow the students to become better prepared and more effective members of the work force.

Don Eshelby, Chairman
Board of Directors
Mid-America Vocational
Curriculum Consortium

PREFACE

For many years those responsible for teaching Diesel Engine Mechanics have felt a need for instructional materials to use in this area. A team of teachers, industry representatives, and trade and industrial education staff members accepted this challenge and have produced manuals which will meet the needs of many types of courses where students are expected to become proficient in the area of diesel engine repair. The MAVCC Diesel Engine Mechanics publication is designed to include the basic information needed to be able to repair most diesel engines.

Every effort has been made to make this publication basic, readable, and by all means usable. Three vital parts of instruction have been intentionally omitted from this publication: motivation, personalization, and localization. These areas are left to the individual instructors and the instructors should capitalize on them. Only then will this publication really become a vital part of the teaching-learning process.

In addition, we would appreciate your help. We check for content quality, spelling, and typographical errors many times in the development of a manual. It is still possible, however, for an error to show up in a publication.

If, in the use of this publication, you should find something questionable we would appreciate you bringing it to our attention. A copy of the page or pages in question with your suggestions for correction would certainly help us when we revise and update materials.

We're trying to provide you with the best possible curriculum materials and will certainly appreciate your help in detecting areas where possible corrections are needed to maintain the quality you want and deserve.

Ann Benson
Executive Director
Mid-America Vocational
Curriculum Consortium, Inc.

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Appreciation is extended to those individuals who contributed their time and talent to the development of Diesel Engine Mechanics.

The contents of this publication were planned and reviewed by:

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The printing staff of the Oklahoma State Department of Vocational and Technical Education are deserving of much credit for printing this publication.

USE OF THIS PUBLICATION

Instructional Units

The Diesel Engine Mechanics curriculum includes eight sections. Each section consists of one or more units of instruction. Each instructional unit includes some or all of the basic components of a unit of instruction: performance objectives, suggested activities for teacher and students, information sheets, assignment sheets, job sheets, visual aids, tests, and answers to the test. Units are planned for more than one lesson or class period of instruction.

Careful study of each instructional unit by the teacher will help to determine:

A. The amount of material that can be covered in each class period.
B. The skills which must be demonstrated.
    1. Supplies needed
    2. Equipment needed
    3. Amount of practice needed
    4. Amount of class time needed for demonstrations
C. Supplementary materials such as pamphlets and filmstrips that must be ordered.
D. Resource people that must be contacted.

Objectives

Each unit of instruction is based on performance objectives. These objectives state the goals of the course thus providing a sense of direction and accomplishment for the student.

Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction and specific objectives, stating the student performance necessary to reach the unit objective.

Since the objectives of the unit provide direction for the teaching-learning process, it is important for the teacher and students to have a common understanding of the intent of the objectives. A limited number of performance terms have been used in the objectives for this curriculum to assist in promoting the effectiveness of the communication among all individuals using the materials.

Following is a list of performance terms and their synonyms which may have been used in this material:

Name	Identify	Describe
Label	Select	Define
List in writing	Mark	Discuss in writing
List orally	Point out	Discuss orally
Letter	Pick out	Interpret
Record	Choose	Tell how
Repeat	Locate	Tell what
Give		Explain

Order	Distinguish	Construct
Arrange	Discriminate	Draw
Sequence		Make
List in order		Build
Classify		Design
Divide		Formulate
Isolate		Reproduce
Sort		Transcribe
		Reduce
		Increase
		Figure

Demonstrate	Additional Terms Used	
Show your work	Evaluate	Prepare
Show procedure	Complete	Make
Perform an experiment	Analyze	Read
Perform the steps	Calculate	Tell
Operate	Estimate	Teach
Remove	Plan	Converse
Replace	Observe	Lead
Turn off/on	Compare	State
(Dis) assemble	Determine	Write
(Dis) connect	Perform	

Reading of the objectives by the student should be followed by a class discussion to answer any questions concerning performance requirements for each instructional unit.

Teachers should feel free to add objectives which will fit the material to the needs of the students and community. When teachers add objectives, they should remember to supply the needed information, assignment and/or job sheets, and criterion tests.

Suggested Activities

Each unit of instruction has a suggested activities sheet outlining steps to follow in accomplishing specific objectives. The activities are listed according to whether they are the responsibility of the instructor or the student.

Instructor: Duties of the instructor will vary according to the particular unit; however, for best use of the material they should include the following: provide students with objective sheet, information sheet, assignment sheets, and job sheets; preview filmstrips, make transparencies, and arrange for resource materials and people; discuss unit and specific objectives and information sheet; give test. Teachers are encouraged to use any additional instructional activities and teaching methods to aid students in accomplishing the objectives.

Students: Student activites are listed which will help the student to achieve the objectives for the unit.

Information Sheets

Information sheets provide content essential for meeting the cognitive (knowledge) objectives of the unit, the teacher will find that information sheets serve as an excellent guide for presenting the background knowledge necessary to develop the skills specified in the unit objective.

Students should read the information sheets before the information is discussed in class. Students may take additional notes on the information sheets.

Transparency Masters

Transparency masters provide information in a special way. The students may see as well as hear the material being presented, thus reinforcing the learning process. Transparencies may present new information or they may reinforce information presented in the information sheets. They are particularly effective when identification is necessary.

Transparencies should be made and placed in the notebook where they will be immediately available for use. Transparencies direct the class's attention to the topic of discussion. They should be left on the screen only when topics shown are under discussion.

Job Sheets

Job sheets are an important segment of each unit. The instructor should be able to and in most situations should demonstrate the skills outlined in the job sheets. Procedures outlined in the job sheets give direction to the skill being taught and allow both student and teacher to check student progress toward the accomplishment of the skill. Job sheets provide a ready outline for students to follow if they have missed a demonstration. Job sheets also furnish potential employers with a picture of the skills being taught and the performances which might reasonably be expected from a person who has had this training.

Assignment Sheets

Assignment sheets give direction to study and furnish practice for paper and pencil activities to develop the knowledges which are necessary prerequisites to skill development. These may be given to the student for completion in class or used for homework assignments. Answer sheets are provided which may be used by the student and/or teacher for checking student progress.

Test and Evaluation

Paper-pencil and performance tests have been constructed to measure student achievement of each objective listed in the unit of instruction. Individual test items may be pulled out and used as a short test to determine student achievement of a particular objective. This kind of testing may be used as a daily quiz and will help the teacher spot difficulties being encountered by students in their efforts to accomplish the unit objective. Test items for objectives added by the teacher should be constructed and added to the test.

Test Answers

Test answers are provided for each unit. These may be used by the teacher and/or student for checking student achievement of the objectives.

DIESEL ENGINE MECHANICS

INSTRUCTIONAL/TASK ANALYSIS

Job Training: What the Worker Should Be Able to Do (Psychomotor)	Related Information: What the Worker Should Know (Cognitive)
SECTION A--UNIT I: ORIENTATION	
	1. Occupational outlook
	2. Places for employment
	3. Steps in shopwork
	4. Engine applications
5. Complete a personal information sheet	
UNIT II: SHOP SAFETY	
	1. Colors of the color code
	2. Personal safety rules
	3. Shop safety rules
	4. Sources of accidents
	5. Classes of fires
	6. Types of fire extinguishers
7. Complete a safety pledge form	
8. Complete individual student shop safety inspection	
UNIT III: BASIC SHOP TOOLS	
	1. Types of tools
	2. Precautions in using a hacksaw
	3. Parts of a twist drill
	4. Pullers
	5. Measuring tools
	6. Methods of maintaining shop tools

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
7. Read the micrometer	
8. Read the vernier micrometer	
9. Sharpen a twist drill	
10. Drill holes with a drill press	
11. Reshape a cold chisel	
12. Cut flat metal with a cold chisel	
13. Dress a grinding wheel	
14. Fit a screwdriver	
15. Replace a hammer handle	
16. Tin a soldering iron	
17. Solder a lap joint	
18. Check a torque wrench for accuracy	
19. Draw file a flat surface	
20. Draw a twist drill to correct center	
21. Use the outside micrometer	
22. Use the vernier micrometer	
23. Cut external threads	
24. Cut internal threads	

UNIT IV: TEST EQUIPMENT AND SERVICE TOOLS

1. Types of testing tools
2. Types of service tools
3. Testing tool functions
4. Service tool functions

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	UNIT V: FASTENERS
	1. Types of fasteners
	2. Bolt head styles
	3. Thread measurement
	4. Grade markings
	5. Nuts
	6. Special purpose nuts
	7. Seized nuts
	8. Types of washers
	9. Tools to restore threads
	10. Restore internal threads
	11. Devices for locking nuts or holes
	12. Machine screw head design
	13. Types of snap rings
	SECTION B--UNIT I: ENGINE OPERATING PRINCIPLES
	1. Basic parts of a diesel engine
	2. Functions of parts
	3. Operation of engine
	4. Strokes
	5. Two and four stroke differences
	6. Differences in gasoline and diesel engines
	UNIT II: DIESEL FUELS
	1. Diesel fuel combustion cycle
	2. Properties of diesel fuel

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	3. Crude oil by-products
	4. Cetane fuels
	5. ASTM standards
	6. Diesel engine knock
	7. Diesel smoke
	8. Storing diesel fuel
	9. Protecting fuel quality
UNIT III: ENGINE LUBRICANTS	
	1. Engine oil functions
	2. Characteristics of engine oils
	3. SAE viscosity numbers
	4. API classification system
	5. Oil contaminants
	6. Oil additives
	7. Selection of oil
UNIT IV: COOLANTS	
	1. Types of cooling systems
	2. Parts of a liquid cooling system
	3. Water as a coolant
	4. Antifreeze
	5. Boiling temperature of common coolants
	6. Maintenance of the cooling system

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
UNIT V: BEARINGS	
	1. Bearing functions
	2. Types of Bearings
	3. Load forces
	4. Advantages and disadvantages of bearings
	5. Materials for constructing bearings
	6. Lubricating bearings
	7. Causes of bearing failure
	8. Bearing crush
	9. Anti-friction bearings
	10. Load carrying capacity
	11. Races
	12. Designs of ball bearings
	13. Types of needle bearings
	14. Mountings
15. Remove and install plain bearings	
16. Remove and install anti-friction bearings	
17. Check preload bearing setting, spring scale method	
UNIT VI: SEALS	
	1. Uses
	2. Types
	3. Dynamic seals
	4. Static seals
	5. Types of static seals
	6. Catagories of sealants

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
7. Install a radial lip seal	
SECTION C--UNIT I: CYLINDER HEAD ASSEMBLY	
	1. Parts in a cylinder head assembly
	2. Forms of head castings
	3. Parts of a valve assembly
	4. Valve rotators
	5. Valve arrangements
	6. Locations for turbulence chambers
	7. Forms of engine movements
8. Remove, inspect and install a cylinder head	
9. Disassemble and service valve train	
10. Service valve guides, valve seats, valve seat inserts and assemble valve train	
UNIT II: PISTON AND CONNECTING ROD ASSEMBLIES	
	1. Parts of piston and connecting rod assemblies
	2. Piston functions
	3. Piston ring functions
	4. Piston ring types
	5. Piston ring joints
	6. Causes of oil consumption
	7. Types of piston pins
	8. Construction of cap ends

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
9. Service piston and install piston rings	
10. Service piston pin and connecting rod	
11. Install precision-insert connecting rod bearings	
UNIT III: CAMSHAFT, GEAR TRAIN, AND ENGINE TIMING	
	1. Parts actuated by camshafts
	2. Parts of camshaft
	3. Parts of a valve train
	4. Valve timing
	5. Gear train
6. Remove service and install a camshaft	
7. Adjust valve clearance on a valve-in-head engine	
UNIT IV: FRAMES AND CYLINDER HEADS	
	1. Stationary parts
	2. Purpose of through-bolts on A frame
	3. Cylinder construction
	4. Removable liners
	5. Wet and dry liners
6. Inspect, remove and replace a cylinder liner	
UNIT V: CRANKSHAFTS AND BEARINGS	
	1. Crankshaft construction
	2. Parts of a crankshaft
	3. Throws
	4. Crankshaft balance

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	5. Crankshaft lubrication
	6. Bearing blocks
	7. Bearing crush
	8. Oil grooves
	9. Thrust bearings
	10. Bearing failure
	11. Flywheel functions
12. Disassemble, inspect, and replace crankshaft assembly and engine bearings	

SECTION D--UNIT I: LUBRICATION SYSTEMS

	1. Functions
	2. Types
	3. Components
	4. Component purposes
	5. Oil filters
	6. Oil pumps
	7. Oil contamination
	8. Lubricating valves
	9. Oil cooler
	10. Pressure indicating systems
11. Check and adjust oil pressure on a live engine	

UNIT II: COOLING SYSTEMS

	1. Functions
	2. Engine overheating
	3. Engine running to cold
	4. Parts of liquid cooling system

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	5. Types of radiators
	6. Functions of pressure caps
	7. Types of fans
	8. Types of fan controls
	9. Functions of thermostat
	10. Coolant filters and conditioners
	11. Restrictions to flow
	12. Water pumps
13. Reverse flush a radiator	
14. Test thermostat action	
15. Test for exhaust gas leakage and air in cooling system	

UNIT III: AIR INTAKE AND EXHAUST SYSTEMS

	1. Air intake system parts
	2. Exhaust system parts
	3. Air cleaners
	4. Methods of cylinder scavenging
	5. Superchargers
	6. Turbochargers
7. Test an engine for air flow restriction	
8. Inspect a turbocharger for satisfactory operation	
9. Remove, disassemble, service, assemble, and install a turbocharger	
10. Disassemble, service, repair, and assemble a supercharger	

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	UNIT IV: STARTING SYSTEMS
	1. Major types
	2. Services of electricity for starting
	3. Compressed air starting
	4. Components of air starting system
	5. Components of hydraulic starting system
	6. Gasoline starting systems
	7. Electric starting systems
	8. Low temperature starting aids
	SECTION E--UNIT I: FUEL SYSTEM COMPONENTS
	1. Parts of a fuel system
	2. Functions of components
	3. Fuel injection system
	4. Fuel tank maintenance
	5. Air pressure testing for leaks
	6. Soldering and welding safety
	7. Types of fuel lines
	8. Transfer pumps
	9. Types of filters
	10. Series and parallel filters
	11. Types of injector systems
	12. Jerk pump system
	13. Methods of injecting fuel

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
UNIT II: DISTRIBUTOR TYPE INJECTION PUMP	
	1. Parts
	2. Rotating parts of a distributor pump
	3. Principles of operation
	4. Fuel flow circuit
	5. Functions of the end plate
	6. Optional features
7. Remove a distributor type pump from an engine	
8. Bench test a distributor type pump	
9. Install a distributor type pump on an engine	
UNIT III: IN-LINE INJECTION PUMP	
	1. Main parts
	2. Fuel flow circuit
	3. Hand primer
	4. Transfer pump
	5. Injection pump
	6. Control rack and sleeve
	7. Delivery valve
	8. Plunger and rack positions
9. Bench test an in-line injection pump	
UNIT IV: UNIT INJECTOR	
	1. Parts
	2. Functions
	3. Fuel flow
	4. Injection metering

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
5. Remove unit injector from engine	
6. Disassemble unit injector	
7. Assemble unit injector	
8. Test unit injector	
9. Install unit injector	
UNIT V: PT FUEL SYSTEMS	
	1. Parts
	2. Pump assembly
	3. Operation of pump
	4. Pulsation damper
	5. Mechanical governor
	6. Types of P.T. injectors
7. Remove and install flange type PT injectors	
8. Remove and install PT (type B, C, and D) injectors	
9. Adjust injector plunger and valves using torque method	
10. Install PT-R fuel pump and adjust high and low engine idle	
11. Test and adjust PT-G fuel pump	
UNIT VI: INJECTION NOZZLES	
	1. Functions
	2. Moving parts
	3. Types of valves
	4. Nozzle characteristics
	5. Operation
	6. Adjustment
7. Remove, service and test an injection nozzle	

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	UNIT VII: GOVERNOR
	1. Purposes
	2. Types
	3. Mechanical and hydraulic
	4. Special governor functions
	5. Characteristics
	6. Effect of load increase
	7. Effect of load decrease
	8. Flyweights
	9. Isochronous governor
	SECTION F--UNIT I: PRINCIPLES OF ELECTRICITY
	1. Particles found in an atom
	2. Electron flow
	3. Atomic theory
	4. Sources of electricity
	5. Basic circuit components
	6. Conductors and insulators
	7. Copper as a conductor
	8. Units of measure
	9. Resistance
	10. Schematic symbols
	11. Ohm's law
	12. Types of electrical circuits
	13. Rules for series circuits
	14. Rules for parallel circuits
	15. Magnetism

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	16. Electromagnetic induction
	17. DC and AC
18. Solve problems using ohm's law formula	

UNIT II: STORAGE BATTERIES

	1. Functions
	2. Parts
	3. Charging process
	4. Safety for batteries
	5. Service free batteries
6. Clean and service a battery	
7. Remove and replace a battery	
8. Measure battery electrolyte with a hydrometer	
9. Load test a battery	
10. Charge test a battery for three minutes	

UNIT III: STARTING CIRCUITS

	1. Purpose
	2. Major parts
	3. Functions
	4. Starting motors
	5. Starter field circuits
	6. Counter GMF
	7. Starting switches
	8. Starter drives

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
9. Remove and replace a starter	
10. Disassemble, test, and reassemble a starter	
11. Test starter circuit (no-load)	
12. Recondition starting motor armature	
UNIT IV: IGNITION CIRCUITS	
	1. Purpose
	2. Components
	3. Functions
	4. Primary and secondary circuits
	5. Components of the distributor
	6. Operation of circuit
	7. Transistorized systems
	8. Capacitive discharge systems
9. Remove and install a distributor	
10. Remove and replace contact points and condenser	
11. Adjust dwell on an externally adjustable distributor	
12. Check and set ignition timing	
13. Remove, service, and replace spark plugs	
UNIT V: GENERATOR CHARGING CIRCUITS	
	1. Purpose
	2. Kinds of circuits
	3. Function of components
	4. Parts of generator
	5. Operating stages

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	6. Current flow
	7. Field circuit
	8. Converting AC to DC
	9. A & B field circuit
	10. Generator regulator components
	11. Uses
	12. Electrical failure
	13. Reverse polarity
14. Test generator output	
15. Remove and replace a generator	
16. Disassemble, test, and reassemble a generator	
17. Test and adjust a regulator unit	

UNIT VI: ALTERNATOR CHARGING CIRCUITS

	1. Purpose
	2. Circuit components and functions
	3. Alternator parts
	4. Advantages
	5. Current production
	6. Stator windings
	7. Alternator control
	8. Transistorized regulator
	9. Operation
	10. Safety rules

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
11. Test the alternator charging circuit and regulator	
12. Remove and replace an alternator	
13. Disassemble, test, and reassemble an alternator	
14. Test and repair a transistorized regulator	

SECTION G--UNIT I: OPERATION AND MAINTENANCE

1. Engine operator duties
2. Starting checklist
3. Running checklist
4. Stopping procedure
5. Performance records
6. Hard starting
7. Failure to come up to speed
8. Misfiring
9. Engine knock
10. Overheating

UNIT II: DIAGNOSIS AND TESTING OF ENGINES

1. Steps involved
2. Checkpoints
3. Operating checks
4. Dynamometer
5. Horsepower
6. Improper operation

7. Complete a troubleshooting guide	
8. Load test an engine with a dynamometer	

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
9. Test engine cylinder compression	
10. Check air intake system for restrictions	
11. Check crankcase pressure, exhaust back pressure, and air box pressure	
UNIT III: TUNE-UP AND ADJUSTMENT	
	1. Visual inspection checklist
2. Tune-up and service a diesel engine	
3. Tune-up a Cummins diesel engine	
4. Tune-up a General Motors diesel engine	
5. Tune-up a Caterpillar diesel engine	
UNIT IV: ENGINE STORAGE	
	1. Climate effects
	2. Systems to be protected
3. Prepare an engine for temporary storage	
4. Prepare an engine for permanent storage	
5. Prepare a stored engine for service	
SECTION H--UNIT I: ARC WELDING	
	1. Safety
	2. Kinds of welders
	3. Equipment
	4. Types of electrodes
	5. Electrode sizes
	6. Electrode numbers
	7. Electrode counting
	8. Current

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	9. Striking an arc
	10. Arc length
	11. Weld types
	12. Welding positions
	13. Poor welds
14. Start, stop and restart a bead	
15. Construct a pad weld	
16. Construct a butt weld	
17. Make a pad in the vertical up position	
18. Make a pad in the overhead position	
UNIT II: Oxyacetylene Cutting	
	1. Cutting outfit parts
	2. Torch parts
	3. Safety ruler
	4. Cutting flames
	5. Poor cuts
	6. Backfire
	7. Flashback
8. Set up equipment for oxyacetylene cutting	
9. Turn on, light, adjust to a neutral flame, and turn off oxyacetylene cutting equipment	
10. Make ninety-degree cuts on mild steel and restart a cut	
11. Cut round stock	

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
UNIT III: OXYACETYLENE FUSION WELDING	
	1. Welding equipment parts
	2. Weld quality
	3. Tip size
	4. Filler rod
	5. Flame types
6. Turn on, light, adjust, and turn off oxyacetylene welding equipment	
7. Construct a corner weld without filler rod	
8. Lay beads on gauge metal without filler rod	
9. Lay beads on gauge metal with filler rod	
10. Weld butt joints with filler rod	
UNIT IV: OXYACETYLENE BRAZE WELDING	
	1. Braze welding advantages
	2. Conditions of metal surface
	3. Removing oxides
	4. Flux
	5. Molten bronze reaction
6. Braze weld a square groove butt joint	

SUGGESTED TRAINING FACILITIES

The suggested floor plan is intended to provide training facilities for approximately 120 students with a student-instructor ratio of 15 to 1 and with a class of students being enrolled each semester. The photographs of the various training facilities will illustrate the floor plan and equipment distribution.

Suggested tools and general equipment are listed by training facility area. Also suggested are basic student tool kits to be administered on a loan or purchase plan. This tool list is furnished as a reference and should not be considered mandatory in establishing a diesel program. Final selection of tools and equipment should be made with reference to the type of equipment to be used as training aids and shop space available. It is further recommended that selection and purchase of tools and equipment be made only after evaluation by the program instructor and advisory board.

The main shop and other areas requiring engine operation should be provided with efficient exhaust systems--floor, overhead, or both as needed. Ceiling exhaust blowers are very helpful and necessary. Main engine and equipment shop areas should be provided with adequate floor drains.

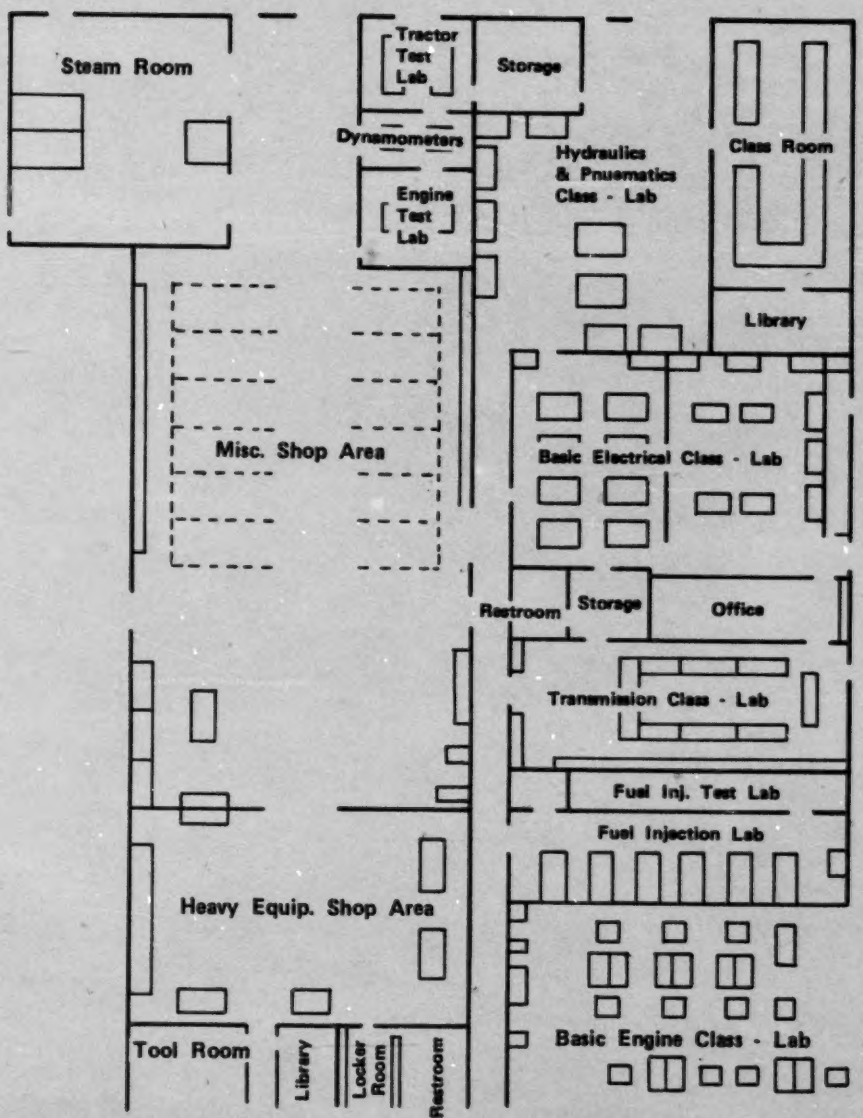
Adequate lighting should be provided for all training facilities. Overhead reel-type drop lights are very economical and successful in main shop areas to provide localized lighting.

The engine dynamometer test area should be provided with a blower or other adequate arrangements to provide the required exhaust accommodations to maintain atmospheric pressures conducive to obtaining correct horsepower and torque readings.

The floor plan will illustrate that the classrooms should be located some distance from the main shop and dynamometer areas so the engine operation noise will not be a disturbing factor.

The fuel injection equipment test area should be dust, temperature, and humidity controlled and pressurized with provided access through a vestibule.

The photographs are intended to be helpful in visually interpreting floor plan and area suggestions.



POSSIBLE DIESEL SHOP DESIGN

TOOL ROOM

1 Industrial puller set
1 Farm tractor puller set
1 1" Socket set (1 5/8"-3 1/2")
1 3/4" Socket set (7/8"-2 3/8")
1 1/2" Deep socket set (3/8"-7/8")
1 Allen set (1/8"-5/8")
1 Tap and die set NC
1 Tap and die set NF
1 Pipe tap set(1/8"-3/4")
1 Pilot reamer set (1/2"-1 1/4")
1 Cylinder hone, rigid
1 Universal sleeve puller set (less sleeve adapter plates)
1 Cylinder ridge reamer
1 Thread chaser
1 Electric drill (1/2")
2 Electric drills (1/4")
1 Set drill bits (1/16"-1/2")
1 Screw extractor set
1 Copper tubing service kit
1 Oil leakage detector
1 Oil leakage detector
1 Hydraulic jack (3-ton)
1 Hydraulic jack (20-ton)
1 Straight edge (4')
1 Volume grease dispenser
1 High pressure grease gun
1 Gear oil dispenser
1 Antifreeze tester
1 Battery hydrometer
4 Creepers (floor)
8 Light drop cords (25') (extension)
1 Sledge hammer
2 Cummins timing fixtures
4 Plastic hammers
4 Piston ring compressors
2 Hacksaws
1 Carburetor tool kit
1 Soldering gun kit
1 Carpenter square
1 Combination square
1 Set box end and open end wrenches (1/4"-2")
1 Set box end and open end wrenches (metric)
1 set metric socket wrenches
1 Injector tube installation kit
1 Detroit blower service kit
1 Hydraulic flo-rater
1 Battery service kit
1 Bushing universal installation tool
6 Wire brushes
6 Carbon scrapers
1 Photo tachometer
1 Radiator pressure tester
1 Magnetic crack detector
1 Water pressure crack detector
1 Universal precup puller set
1 Adjustable wrench (20")
2 Torque wrench (10-150 ft.-lb.)
1 Torque wrench (100-500 ft.-lb.)
1 Tin shears
2 Valve spring compressors
1 Micrometer set (0"-6") with standards and case
4 Micrometers (0-1")
4 Micrometers (1"-2")
4 Micrometers (2"-3")
2 Inside micrometer set (2"-8")
2 Micrometer ball attachment
1 Universal dial test indicator set
1 Cylinder gauge (2 1/10"-6")
1 Micrometer depth gauge (0-6")
2 Oil measures (1 qt.)
2 Oil measures (1 gal.)
1 Pipe wrench (24")
1 Brake spring pliers
2 Battery carriers
2 Water buckets
2 Pairs, booster battery cables
2 Pry bars 23/32" x 24"
2 Rolling head bars 19/34" x 18"
10 Screwdriver (assortment)
12 Files (assortment)
2 Compression tester
1 Leakage tester
2 Log chains (3/8" x 25')
1 Heli-coil kit
1 Stud remover 5/8"-1"
1 Copper tubing service kit (3/16"-5/8")
1 Feeler gauge set

Miscellaneous Supplies:
Miscellaneous oil cans (hand)
Gasket material
Cotter pins (miscellaneous)
Washers
1 Fire extinguisher (20-lb.)

1 Flex stone set or glaze breaker
Miscellaneous drain pans and buckets

FUEL INJECTION EQUIPMENT TEST AND MOCK-UP SHOP

Fuel injection test area:
2 Steel benches and cabinet combination (30" x 6')
4 wall benches (24" x 36")
8 Wall fitting and adapter cabinets (5' x 4' x 1') glass fronts
4 Fuel injection test stands (miscellaneous fittings, adapters, and accessories)
1 Caterpillar fuel injection test stand (miscellaneous fittings, adapters, and special tools)
1 GM unit injector tester and accessories
1 Injector flow comparator
1 Diesel nozzle analyzer
1 Nozzle valve microscope
1 Nozzle valve lapping device and accessories
1 Ultrasonic cleaner
1 Nozzle high pressure cleaner
1 Torque vise
1 Concentricity gauge
2 Diesel nozzle testers
1 Set lapping blocks
1 Jar compound
2 Torque wrenches (5-600 inch-lbs.)
2 Torque wrenches (10-150 ft.-lbs.)
1 Compression tester
2 Fuel system analysis kit
8 Pump and nozzle (miscellaneous tool and service) kits
1 Universal dial test indicator set
1 Micrometer depth gauge (0"-6")
2 Micrometers (0"-1")
2 Micrometers (1"-2")
Miscellaneous items
Temperature and dust control equipment
Supplies (calibrating oil, cleaning solvent, and janitorial supplies)
Fuel injection mock-up shop
5 Steel benches and cabinet combination (30" x 6')
5 Vises (4")

30 Parts pans
1 Hand press (3-ton)
10 Steel racks (3. x 4., equipment)
1 small parts cleaner
1 Smokemeter (with stand)
6 Allen wrench sets (.028"-1/2")
7 Air hoses and fittings
Miscellaneous cutaway and demonstration equipment
Training mockup components

MAIN SHOP AREA

15 Steel benches (30" x 72")
15 Vises (4")
15 Parts racks (wood fabricated)
1 Portable floor jack (10-ton)
1 Portable floor jack (4-ton)
6 HD engine stands
2 PTO Dynamometers
4 Chasis Dynamometer
1 Hydraulic press (75-ton)
1 Hand press (3-ton)
1 Clutch pressure plate adjusting fixture
1 10" Lathe and attachments
1 3/8" Drill press (bench)
1 3/4" Drill press (floor)
1 Connecting rod alignment fixture and adapters
2 Valve grinders
2 Valve seat grinders
1 Air compressor (3 h.p.)
Air hose and fittings
1 Small parts cleaners
1 Arc welder
1 Gas welding equipment (D.S.)
2 Pedestal grinders (10")
1 Mobile floor crane (4,000 lbs.)
1 Valve spring tester
Exhaust ventilating system
3 Fire extinguishers (20-lb.)

4 Farm tractor jack stands
Supplies (cleaning solutions and janitorial supplies)
Miscellaneous engines and tractors

BASIC ENGINE CLASSROOM SHOP COMBINATION

1 Blackboard and equipment
1 Instructor desk and chair
20 Classroom chairs (tablet arm)
1 Overhead projector
1 Film strip projector
17 Steel benches (30" x 6')
10 Vises (4")
1 Valve grinder
1 Valve seat grinder
1 Connecting rod aliner
1 Valve spring tester
1 Bench grinder (8")
1 Small parts washer
1 Battery charger
6 Batteries (12-volt)
12 Engines
12 Engines
Air hose and fittings
2 Torque wrenches (200 ft.-lbs.)
2 Torque wrenches (250 ft.-lbs.)
2 Piston ring compressors
2 Valve spring compressors
Miscellaneous small tools

DYNAMOMETER ROOM

Engine dynamometer (500 h.p.)
1 Engine dynamometer (700 h.p.)
2 Portable cooling columns
2 Engine stands (48" x 104")
1 Universal front engine mounts and adapter kit
1 Universal rear engine mounts and adapter kit
1 Engine cooling column interconnecting kit
1 Cooling column to engine adapter kit
2 Guard assemblies
8 Pedestals H.D.
2 Drive shafts H.D.
2 Farm tractor PTO drive shafts

BASIC ELECTRICAL CLASSROOM AND SHOP COMBINATION

1 Blackboard and equipment
1 Overhead projector
1 Film strip projector
1 Instructor desk and chair
15 Tables (30" x 6')
20 Chairs (swivel)
4 Steel racks (demonstration equipment)
12 Steel benches (30" x 6')
6 Generator test stands (drives)
2 Engines
2 Engine stands
3 Distributor testers
5 Volt-ampere testers
2 Battery starter testers
1 Battery tester
5 Vises (4")
1 Battery charger
1 Load bank
2 Armature testers
2 Ohmmeters
Miscellaneous jumper leads
6 Batteries (12-volt)
2 Generator field controls
4 Field rheostats
2 Pairs, battery booster cables
Miscellaneous tools
Electrical components (training)

STEAM AND HOT TANK ROOM

1 Steam cleaner
1 Hot tank and burner

BASIC HAND TOOL SET

1 tool box
1 Socket set, 1/4" square drive, composition:
1 ratchet
9 Sockets, 6 pt., (3/16" thru 1/2 m.)
1 Flex t-handle
1 Socket set, 3/8" square drive, composition:
1 Ratchet
7 Sockets, 12 pt. (3/8" thru 3/4")
8 Sockets, deep well, 12 pt. (3/8" thru 13/16")
3 Extension bars, (3", 6" and 10")
2 Socket adapters, (3/8" to 1/4" and 3/8" and 3/8" to 1/2")
3 Screwdriver bits, (.030, .039, .055)

1 Socket set, 1/2" square drive, composition
1 Ratchet
12 Sockets, 12 pt. (7/16" thru 1 1/2")
11 Deep sockets, 12 pt. (1/2" thru 1 1/8")
1 Spark plug socket (13/16")
1 Flex t-handle
1 Universal joint
3 Extension bars (3", 6", and 10")
1 Speeder (18")
1 Slide bar
1 Cross bar
2 Flex t-handles (15" and 18")
2 Socket adapters (1/2" to 3/8" and 1/2" to 3/4")

3 Wrench sets, composition
16 Combination wrenches (1/4" thru 1 1/8")
9 Open-end wrenches (1/4" x 5/16" thru 1 1/16" x 1 1/8")
11 Box-end wrenches (1/4" x 5/16" thru 1 1/16" x 1 1/4")
3 Flare nut wrenches (3/8 x 7/16 thru 5/8 x 11/16)

Miscellaneous tools
3 Phillips screwdrivers (Nos. 1, 2, and 3)
1 Offset screwdriver
4 Standard screwdrivers (3/16 x 4, 1/4 x 6, 5/16 x 8 and Stubby)
1 Line-up punch (12")
1 Punch and chisel set, 12 piece
6 Pliers, bent needle nose; battery pliers; diagonal/cutting pliers; slip joint pliers/ hose clamp pliers; locking pliers 10"
1 Hex key set, 11 pieces
1 Hacksaw with 10 extra blades
2 Hammers, ball pien (16 oz. and 40 oz.)
1 Hammer, (8-12 oz.) no-bounce, fiber tip
1 Rolling wedge bar (16")
1 Stainless steel rule
1 Gasket scraper
1 Ignition tile
2 Files, half-round (8" and 10")
1 File, round (6")
1 File, mil (10")
2 Feeler gauge, nonmagnetic (standard and long leaf)
1 Scratch awl
1 Flashlight (D size batteries)

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ORIENTATION
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to list facts concerning the occupational outlook for diesel mechanics and select places of employment. The student should also be able to list student requirements for entry into the diesel program and select steps involved in diesel shopwork. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. List three facts concerning the occupational outlook for diesel mechanics.
2. Select places that employ diesel mechanics.
3. List student requirements for the diesel mechanics program.
4. Select steps involved in diesel shopwork.
5. List diesel engine applications.
6. Complete a personal information sheet.

ORIENTATION
UNIT I

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information and assignment sheets.

C. Discuss unit and specific objectives.

D. Discuss information and assignment sheets.

E. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete assignment sheet.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Assignment Sheet #1--Complete a Personal Information Sheet

D. Test

E. Answers to test

II. Reference--*Occupational Outlook Handbook.* Bureau of Labor Statistics/Department of Labor, 1976.

ORIENTATION
UNIT I

INFORMATION SHEET

I. Occupational outlook

A. Job opportunities result each year from the need to replace experienced mechanics who are promoted, retired, or transfered to related fields of work

B. Number of diesel engine applications increases each year requiring more mechanics to service them

C. Demand for diesel power has increased due to the added economy, endurance, and efficiency of the diesel engine as compared to other power units

II. Places of employment for diesel mechanics

A. Independent repair shops

B. Service departments of dealers and distributors

C. Sales agencies and manufacturers of diesel engines

D. Truck leasing companies

E. Federal, state, and local government vehicle maintenance depots

F. Electric power plants

G. Railroad locomotive shops

H. Fuel injection repair station

III. Student requirements for the diesel mechanics program

A. Operate the shop equipment correctly

B. Be safety conscious; follow safety regulations

C. Take instructions readily; follow directions

D. Be a good citizen

E. Control temper

F. Have enthusiasm about work

INFORMATION SHEET

G. Have pride in the trade and workmanship

H. Be conscious of waste in materials and man-hours

I. Be punctual

IV. Steps involved in diesel shopwork

A. Troubleshooting

B. Disassembly

C. Measuring

D. Metal work or machining

E. Installing new parts

F. Reassembly

G. Adjustments and testing

V. Diesel engine applications

A. Electric power plants

B. Marine engines

C. Farm tractors and equipment

D. Road building equipment

E. Automotive vehicles

(NOTE: These vehicles include trucks, buses, and automobiles.)

F. Rail locomotives

G. Construction equipment

ORIENTATION
UNIT I

ASSIGNMENT SHEET #1--COMPLETE A PERSONAL INFORMATION SHEET

Complete the following personal data and turn in to the instructor.

NAME: _____

HOME SCHOOL: _____

AGE: _____

BIRTH DATE: _____

GRADE CLASSIFICATION: _____

OCCUPATIONAL OBJECTIVE: _____

_____

SOCIAL SECURITY NUMBER: _____

PARENTS' NAMES: _____

PARENTS' OCCUPATIONS: _____

EMERGENCY TELEPHONE NUMBER: _____

ORIENTATION
UNIT I

NAME_____

TEST

1. List three facts concerning the occupational outlook for diesel mechanics.

   a.

   b.

   c.

2. Select the places that employ diesel mechanics by placing an "X" in the appropriate blanks.

   _____a. Sales agencies and manufacturers of diesel engines

   _____b. Motorcycle sales agencies

   _____c. Lawnmower repair shop

   _____d. Independent repair shops

   _____e. Electric power plants

   _____f. Service departments of dealers and distributors

   _____g. Railroad locomotive shops

   _____h. Fuel injection repair station

3. List six student requirements for the diesel mechanics program.

   a.

   b.

   c.

   d.

   e.

   f.

4. Select the steps involved in diesel shopwork by placing an "X" in the appropriate blanks.

_____a. Repair estimating

_____b. Disassembly

_____c. Metal work or machining

_____d. Measuring

_____e. Reassembly

_____f. Sales

_____g. Installing new parts

_____h. Adjustments and testing

_____i. Troubleshooting

5. List five diesel engine applications.

a.

b.

c.

d.

e.

6. Complete a personal information sheet.

(NOTE: If this activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

ORIENTATION
UNIT I

ANSWERS TO TEST

1. a. Job opportunities result each year from the need to replace experienced mechanics who are promoted, retired, or transfered to related fields of work

   b. Number of diesel engine applications increases each year requiring more mechanics to service them

   c. Demand for diesel power has increased due to the added economy, endurance, and efficiency of the diesel engine as compared to other power units

2. a, d, e, f, g, h

3. Any six of the following:

   a. Operate the shop equipment correctly

   b. Be safety conscious; follow safety regulations

   c. Take instructions readily; follow directions

   d. Be a good citizen

   e. Control temper

   f. Have enthusiasm about work

   g. Have pride in the trade and workmanship

   h. Be conscious of waste in materials and man-hours

   i. Be punctual

4. b, c, d, e, g, h, i

5. Any five of the following:

   a. Electric power plants

   b. Marine engines

   c. Farm tractors and equipment

   d. Road building equipment

e. Automotive vehicles

f. Rail locomotives

g. Construction equipment

6. Evaluated to the satisfaction of the instructor

SHOP SAFETY
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to recognize unsafe situations, list general shop and personal safety rules, and select the correct fire extinguisher for use in case of fire. The student should also be able to recognize the uses of the safety color code, complete a safety pledge form, and complete an individual shop safety inspection. This knowledge will be evidenced through demonstration and by scoring one hundred percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with shop safety to the correct definitions.
2. Match the colors of the safety color code to the correct applications.
3. List personal safety rules.
4. List general shop safety rules.
5. Match possible sources of accidents to the injury which may occur.
6. Match the four classes of fire to the correct statements defining each class.
7. Match the type or types of fire extinguishers to the class of fire they are used on.
8. Complete safety pledge form.
9. Complete individual student shop safety inspection.

SHOP SAFETY
UNIT II

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information and assignment sheets.

C. Make transparency.

D. Discuss unit and specific objectives.

E. Discuss information and assignment sheets.

F. Demonstrate the use of fire extinguishers.

G. Take students on tour of shop prior to completion of Assignment Sheet #2.

H. Have a speaker from the local fire department demonstrate the use of fire extinguishers.

I. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete assignment sheets.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency master: TM 1--Types of Fire Extinguishers

D. Assignment sheets

1. Assignment Sheet #1--Complete Safety Pledge Form

2. Assignment Sheet #2--Complete Individual Student Shop Safety Inspection

E. Test

F. Answers to test

II. References:

A. *The ABC's of Fire Protection.* Belleville, New Jersey: Walter Kidde and Company.

B. *An Accident Prevention Program for School Shops and Laboratories.* Office of Education/U.S. Department of Health, Education, and Welfare.

C. *Safety Practices and Procedures in School Shops.* New Jersey: Division of Vocational Education/Department of Education.

D. Strong, Merle E. *Accident Prevention Manual.* American Technical Society, 1975.

E. *OSHA Safety and Health Standards Digest.* Occupetional Safety and Health Administration/U.S. Department of Labor, June 1975.

F. *Federal Register.* Volume 37, Part II. Occupational Safety and Health Standards/Department of Labor, 1972.

SHOP SAFETY
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Safety--State or condition of being free from danger, risk, or injury

B. Accident--Any suddenly occurring, unintentional event which causes injury or property damage

C. First aid--Immediate, temporary care given the victim of an accident or sudden illness until the services of a physician can be obtained

D. Liability--Legal responsibility which binds an individual in law and justice to do something which may be enforced by action

II. Colors and applications of the safety color code

A. Green--Designates "Safety" and the location of first aid equipment

B. Yellow--Designates caution and for marking physical hazards

C. Orange--Designates dangerous parts of equipment which may cut, crush, shock, or otherwise injure

D. Red--Used to identify the location of fire fighting equipment and apparatus

(NOTE: Emergency fire exits shall be designated in red. Buttons or levers for electrical switches used for the stopping of machinery should be designated in red. Gasoline cans should be painted red with additional identification in the form of a yellow band around the can.)

E. Blue--Designates caution against starting equipment while it is being worked upon, or against the use of defective equipment

(NOTE: A blue tag should be lettered "Out of Order.")

F. Black, white, or combinations of black and white--Designates traffic and housekeeping markings

III. Personal safety rules

A. Wear shop clothing appropriate to the activity being performed

B. Confine long hair before operating rotating equipment

INFORMATION SHEET

C. Always wear eye protection when using grinding wheels, rotating brushes, and as required

D. Remove ties when working around machine tools or rotating equipment

E. Remove rings and other jewelry when working in the shop

F. Conduct yourself in a manner conducive to safe shop practices

G. Keep mentally alert to shop hazards

IV. General shop safety rules

A. Keep all hand tools clean and in safe working order

B. Report any defective tools, machines, or other equipment to the instructor

Example: A loose hammer head is a defective tool

C. Retain all guards and safety devices except with the specific authorization of the instructor

D. Operate powered equipment only after receiving instruction on how to operate the machine safely

E. Report all accidents to the instructor regardless of nature or severity

F. Turn off the power before leaving a machine tool

G. Make sure all guards and barriers are in place and adjusted properly before starting a machine tool

H. Disconnect the power from machine tools before performing any maintenance task

I. Use a solvent only after determining its properties, what kind of work it has to do, and how to use it

J. Use correct and proper size wrenches for nuts, bolts, and objects to be turned or held

K. Keep the shop or laboratory floor clear of tools, scraps, and litter

L. Clean up any spilled liquids immediately

M. Store oily rags or oily waste in metal containers

INFORMATION SHEET

N. Clean the chips from a machine with a brush; do not use a rag or bare hands

O. Use proper support for all heavy objects

P. Practice tool motto: "Get, use, and put away"

V. Sources of accidents and injuries which may occur

A. Horseplay--May cause person or persons to fall against sharp objects or moving machinery

B. Air hose--One blast may rip clothing or skin

C. Grinder--May cause eye injury from flying sparks or metal chips

D. Batteries--May explode when near open flame or electrical spark

E. Moving parts--May catch fingers or clothing

F. Loose clothing--May catch in rotating parts

G. Tools--Sharp edges may puncture skin

H. Electric power tools--May cause shock if not grounded

I. Lack of or improper supporting device under heavy objects--A fall may cause a fatal injury

J. Lifting heavy objects--May cause severe back injury

VI. Classes of fires

A. Class A--Fires that occur in ordinary combustible materials

Examples: Wood, rags, and rubbish

B. Class B--Fires that occur with flammable liquids

Examples: Gasoline, oil, grease, paints, and thinners

C. Class C--Fires that occur in or near electrical equipment

Examples: Motors, switchboards, and electrical wiring

D. Class D--Fires that occur in combustible metals

Examples: Magnesium, titanium, zirconium, lithium, and sodium potassium

INFORMATION SHEET

VII. Types of fire extinguishers (Transparency 1)

A. Pressurized water--Used for Class A fires

(NOTE: The pressurized water extinguisher usually operates by squeezing a handle or trigger.)

B. Dry chemical--Used on Class B and C fires

(NOTE: The dry chemical extinguisher usually operates by squeezing a handle, trigger, or lever.)

C. Carbon dioxide (CO_2)--Used on Class B and C fires

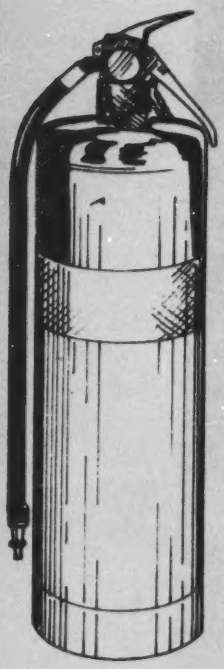
(NOTE: The carbon dioxide (CO_2) extinguisher usually operates by squeezing a handle or trigger.)

D. Powder--Used on Class D fires

(NOTE: The powder should be applied with a scoop or shovel to extinguish a fire. Use an acceptable powder such as Kidde Metal Guard.)

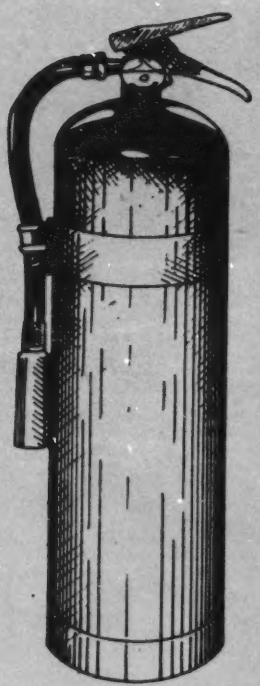
Types of Fire Extinguishers

Pressurized Water for Class A Fires

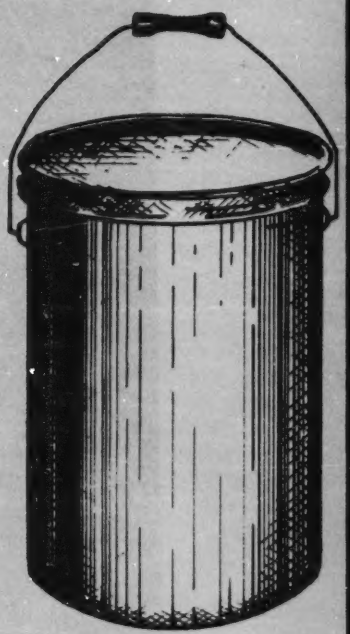


Carbon Dioxide for Class B and C Fires

Dry Chemical for Class B and C Fires



Powder for Class D Fires



SHOP SAFETY
UNIT II

ASSIGNMENT SHEET #1--COMPLETE SAFETY PLEDGE FORM

Read and complete the student safety pledge form by filling in the blanks. Return form to instructor no later than _____.

STUDENT SAFETY PLEDGE FORM

_____ _____ _____, who is enrolled in Vocational _____

_____, will as a part of the shop experience, operate machines,

providing that the parent or guardian gives written permission.

It is understood that each student will be given proper instruction, both in the use of the equipment and in correct safety procedures concerning it, before being allowed to operate the machines. The student must assume responsibility for following safe practices; therefore, we ask that the student subscribe to the following safety pledge.

1. I PROMISE TO FOLLOW ALL SAFETY RULES FOR THE SHOP.
2. I PROMISE NEVER TO USE A MACHINE WITHOUT FIRST HAVING PERMISSION FROM THE INSTRUCTOR.
3. I WILL NOT ASK PERMISSION TO USE A PARTICULAR MACHINE UNLESS I HAVE BEEN INSTRUCTED IN ITS USE, AND HAVE MADE 100% ON THE SAFETY TEST FOR THAT MACHINE.
4. I WILL REPORT ANY ACCIDENT OR INJURY TO THE INSTRUCTOR IMMEDIATELY.

DATE _____ STUDENT'S SIGNATURE _____

I hereby give my consent to allow my son or daughter to operate all machines and equipment necessary in carrying out the requirements of the course in which he/she is enrolled.

DATE _____ PARENT'S SIGNATURE _____
(If required)

Parents are cordially invited to visit the shop to inspect the machines and to see them in operation.

SHOP SAFETY
UNIT II

ASSIGNMENT SHEET #2--COMPLETE INDIVIDUAL STUDENT SHOP SAFETY INSPECTION

Complete the safety inspection checklist by physically conducting an inspection of the shop area.

CHECKING PROCEDURE

Draw a circle around the appropriate letter, using the following letter scheme:

S -- Satisfactory (needs no attention)
A -- Acceptable (needs some attention)
U -- Unsatisfactory (needs immediate attention)

Recommendations should be made in all cases where a "U" is circled. Space is provided at the end of the form for such comments.

A. GENERAL PHYSICAL CONDITION

1.	Machines, benches, and other equipment are arranged to conform to good safety practices	S A U
2.	Condition of stairways and ramps	S A U
3.	Condition of aisles	S A U
4.	Condition of floors	S A U
5.	Condition of walls, windows, and ceiling	S A U
6.	Illumination is safe, sufficient, and well placed	S A U
7.	Ventilation is adequate and proper for conditions	S A U
8.	Temperature control	S A U
9.	Fire extinguishers are of proper type, adequately supplied, properly located, and maintained	S A U
10.	Teacher and pupils know location of and how to use proper type for various fires	S A U
11.	Number and location of exits is adequate and properly identified	S A U

ASSIGNMENT SHEET #2

12.	Walls are clear of objects that might fall	S	A	U
13.	Utility lines are properly identified	S	A	U
14.	Air in shop is free from excessive dust and smoke	S	A	U
15.	Evaluation for the total rating of GENERAL PHYSICAL CONDITION	S	A	U

B. HOUSEKEEPING

1.	General appearance as to orderliness	S	A	U
2.	Adequate and proper storage space for tools and materials	S	A	U
3.	Benches are kept orderly	S	A	U
4.	Corners are clean and clear	S	A	U
5.	Special tool racks, in orderly condition, are provided at benches and machines	S	A	U
6.	Tool, supply, and/or material room is orderly	S	A	U
7.	Sufficient scrap boxes are provided	S	A	U
8.	Scrap stock is put in scrap boxes promptly	S	A	U
9.	Materials are stored in an orderly and safe condition	S	A	U
10.	A spring lid metal container is provided for waste and oily rags	S	A	U
11.	Dangerous materials are stored in metal cabinets	S	A	U
12.	Machines have been color conditioned	S	A	U
13.	Safety cans are provided for flammable liquids	S	A	U
14.	Floors are free of oil, water, and foreign material	S	A	U
15.	Evaluation for the total rating for HOUSEKEEPING	S	A	U

ASSIGNMENT SHEET #2

C. EQUIPMENT

1.	Machines are arranged so that workers are protected from hazards of other machines and passing students	S A U
2.	Danger zones are properly indicated and guarded	S A U
3.	All gears and moving belts are protected by permanent enclosure guards	S A U
4.	All equipment control switches are easily available to operator	S A U
5.	Nonskid areas are provided around machines	S A U
6.	Tools are kept sharp, clean, and in safe working order	S A U
7.	Evaluation for the total rating for EQUIPMENT	S A U

D. ELECTRICAL INSTALLATION

1.	All switches are enclosed	S A U
2.	There is a master control switch for all of the electrical installations	S A U
3.	All electrical extension cords are in safe condition and are not carrying excessive loads	S A U
4.	All machine switches are within easy reach of the operators	S A U
5.	Individual cut-off switches are provided for each machine	S A U
6.	No temporary wiring in evidence	S A U
7.	Evaluation for the total rating for ELECTRICAL INSTALLATION	S A U

ASSIGNMENT SHEET #2

E. PERSONAL PROTECTION (Read only)

1. Goggles or protective shields are provided and required for all work where eye hazards exist
2. If individual goggles are not provided, hoods and goggles are properly disinfected before use
3. Shields and goggles are provided for electric welding
4. Rings and other jewelry are removed by pupils when working in the shop
5. Proper kind of wearing apparel is worn and worn properly for the job being done
6. Leggings and safety shoes are worn in special classes
7. Respirators are provided for dusty or toxic atmospheric conditions such as when spraying in the finishing room
8. Provisions are made for cleaning and sterilizing respirators
9. Students are examined for safety knowledge ability
10. Sleeves are rolled above elbows when operating machines
11. Clothing of students is free from loose sleeves, flopping ties, and loose coats

RECOMMENDATIONS

SHOP SAFETY
UNIT II

NAME_____

TEST

1. Match the terms on the right to the correct definitions.

_____a. Legal responsibility which binds an individual in law and justice to do something which may be enforced by action	1.	Safety
	2.	First aid
	3.	Liability
_____b. Any suddenly occurring, unintentional event which causes injury or property damage	4.	Accident
_____c. State or condition of being free from danger, risk, or injury		
_____d. Immediate, temporary care given the victim of an accident or sudden illness until the services of a physician can be obtained		

2. Match the colors of the safety color code on the right to the correct applications.

_____a. Designates caution and for marking physical hazards	1.	Green
	2.	Black, white, or combinations of black and white
_____b. Used to identify the location of fire fighting equipment and apparatus		
_____c. Designates "Safety" and the location of first aid equipment	3.	Orange
	4.	Blue
_____d. Designates dangerous parts of equipment which may cut, crush, shock, or otherwise injure	5.	Red
	6.	Yellow
_____e. Designates caution against starting equipment while it is being worked upon, or against the use of defective equipment		
_____f. Designates traffic and housekeeping markings		

3. List five personal safety rules.

a.

b.

c.

d.

e.

4. List eight general shop safety rules.

a.

b.

c.

d.

e.

f.

g.

h.

5. Match possible sources of accidents on the right to the injury which may occur.

_____a. May cause person or persons to fall against sharp objects or moving machinery

_____b. One blast may rip clothing or skin

_____c. May cause eye injury from flying sparks or metal chips

_____d. May explode when near open flame or electrical spark

_____e. May catch fingers or clothing

_____f. May catch in rotating parts

_____g. Sharp edges may puncture skin

_____h. May cause shock if not grounded

_____i. A fall may cause a fatal injury

_____j. May cause severe back injury

1. Horseplay
2. Grinder
3. Batteries
4. Air hose
5. Moving parts
6. Loose clothing
7. Electric power tools
8. Tools
9. Lack of or improper supporting device under heavy objects
10. Lifting heavy objects

6. Match the four classes of fire on the right to the correct statements defining each class.

_____a. Fires that occur in ordinary combustible materials	1. Class B
_____b. Fires that occur with flammable liquids	2. Class A
_____c. Fires that occur in or near electrical equipment	3. Class C
_____d. Fires that occur in combustible metals	4. Class D

7. Match the type or types of fire extinguishers on the right to the class of fire they are used on.

_____a. Class A	1. Pressurized water
_____b. Class B	2. Carbon dioxide (CO_2)
_____c. Class C	3. Dry chemical
_____d. Class D	4. Powder

8. Complete safety pledge form.

9. Complete individual student shop safety inspection.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

SHOP SAFETY
UNIT II

ANSWERS TO TEST

1. a. 3
   b. 4
   c. 1
   d. 2

2. a. 6
   b. 5
   c. 1
   d. 3
   e. 4
   f. 2

3. Any five of the following:
   a. Wear shop clothing appropriate to the activity being performed
   b. Confine long hair before operating rotating equipment
   c. Always wear eye protection when using grinding wheels, rotating brushes, and as required
   d. Remove ties when working around machine tools or rotating equipment
   e. Remove rings and other jewelry when working in the shop
   f. Conduct yourself in a manner conducive to safe shop practices
   g. Keep mentally alert to shop hazards

4. Any eight of the following:
   a. Keep all hand tools clean and in safe working order
   b. Report any defective tools, machines, or other equipment to the instructor
   c. Retain all guards and safety devices except with the specific authorization of the instructor
   d. Operate powered equipment only after receiving instruction on how to operate the machine safely
   e. Report all accidents to the instructor regardless of nature or severity
   f. Turn off the power before leaving a machine tool

g. Make sure all guards and barriers are in place and adjusted properly before starting a machine tool

h. Disconnect the power from machine tools before performing any maintenance task

i. Use a solvent only after determining its properties, what kind of work it has to do, and how to use it

j. Use correct and proper size wrenches for nuts, bolts, and objects to be turned or held

k. Keep the shop or laboratory floor clear of tools, scraps, and litter

l. Clean up any spilled liquids immediately

m. Store oily rags or oily waste in metal containers

n. Clean the chips from a machine with a brush; do not use a rag or bare hands

o. Use proper support for all heavy objects

p. Practice tool motto: "Get, use, and put away"

5. a. 1
   b. 4
   c. 2
   d. 3
   e. 5
   f. 6
   g. 8
   h. 7
   i. 8
   j. 10

6. a. 2
   b. 1
   c. 3
   d. 4

7. a. 1
   b. 2, 3
   c. 2, 3
   d. 4

8. Evaluated to the satisfaction of the instructor

9. Evaluated to the satisfaction of the instructor

BASIC SHOP TOOLS
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify and choose the right tool for the job and maintain them in a safe condition. The student should also be able to repair and sharpen certain tools and be able to accurately read measuring instruments. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Identify basic shop tools.
2. Identify types of screwdrivers.
3. Name two types of hammers.
4. Identify types of pliers.
5. Identify types of wrenches.
6. Identify types of cold chisels.
7. Identify types of punches.
8. Identify types of file teeth.
9. Name precautions for correct use of the hacksaw.
10. Name three principle parts of a twist drill.
11. Name three ways to extract a screw.
12. Identify three types of pullers.
13. Name three shop tools used for measuring speed.
14. List two types of feeler gauges.
15. Distinguish between correct and incorrect methods of using and maintaining basic shop tools.
16. Name four types of micrometers.

17. Read the micrometer settings.

18. Read the vernier micrometer settings.

19. Demonstrate the ability to:

    a. Sharpen a twist drill.

    b. Drill holes with a drill press.

    c. Reshape a cold chisel.

    d. Cut flat metal with a cold chisel.

    e. Dress a grinding wheel.

    f. Fit a screwdriver.

    g. Replace a hammer handle.

    h. Tin a soldering iron.

    i. Solder a lap joint.

    j. Check a torque wrench for accuracy.

    k. Draw file a flat surface.

    l. Draw a twist drill to correct center.

    m. Use the outside micrometer.

    n. Use the vernier micrometer.

    o. Cut external threads.

    p. Cut internal threads.

BASIC SHOP TOOLS
UNIT III

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information, assignment, and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information and assignment sheets.

F. Demonstrate and discuss the procedures outlined in the job sheets.

G. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete assignment and job sheets.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Basic Shop Tools
2. TM 2--Basic Shop Tools (Continued)
3. TM 3--Basic Shop Tools (Continued)
4. TM 4--Types of Screwdrivers
5. TM 5--Types of Pliers

6. TM 6--Types of Wrenches
7. TM 7--Types of Wrenches (Continued)
8. TM 8--Types of Wrenches (Continued)
9. TM 9--Types of Cold Chisels
10. TM 10--Types of Punches
11. TM 11--Types of Files
12. TM 12--Types of Pullers
13. TM 13--Right and Wrong Use of Tools
14. TM 14--Right and Wrong Use of Tools (Continued)
15. TM 15--Right and Wrong Use of Tools (Continued)
16. TM 16--Right and Wrong Use of Tools (Continued)
17. TM 17--Types of Micrometers
18. TM 18--Reading a Micrometer
19. TM 19--Sleeve Readings

    Overlay A--Thimble Sleeve Readings
20. TM 20--Vernier Micrometer Readings

    Overlay B--Vernier Sleeve Readings

D. Assignment sheets

1. Assignment Sheet #1--Read the Micrometer Settings
2. Assignment Sheet #2--Read the Vernier Micrometer Settings

E. Answers to assignment sheets

F. Job sheets

1. Job Sheet #1--Sharpen a Twist Drill
2. Job Sheet #2--Drill Holes with a Drill Press
3. Job Sheet #3--Reshape a Cold Chisel
4. Job Sheet #4--Cut Flat Metal with a Cold Chisel
5. Job Sheet #5--Dress a Grinding Wheel

6. Job Sheet #6--Fit a Screwdriver
7. Job Sheet #7--Replace a Hammer Handle
8. Job Sheet #8--Tin a Soldering Iron
9. Job Sheet #9--Solder a Lap Joint
10. Job Sheet #10--Check a Torque Wrench for Accuracy
11. Job Sheet #11--Draw File a Flat Surface
12. Job Sheet #12--Draw a Twist Drill to Correct Center
13. Job Sheet #13--Use the Outside Micrometer
14. Job Sheet #14--Use the Vernier Micrometer
15. Job Sheet #15--Cut External Threads
16. Job Sheet #16--Cut Internal Threads

G. Test

H. Answers to test

II. References:

A. *Fundamentals of Service: Shop Tools.* Moline, Illinois: Deere and Company, 1971.

B. *ABC's of Hand Tools.* Detroit, Michigan: General Motors Corporation, General Motors Building, 1945.

BASIC SHOP TOOLS
UNIT III

INFORMATION SHEET

I. Basic shop tools (Transparencies 1, 2, and 3)

A. Common screwdriver

B. Ball peen hammer

C. Slip joint pliers

D. Combination box and open-end wrench

E. Flat cold chisel

F. Center punch

G. Flat file

H. Hacksaw

I. Vise

J. "C" clamp

K. Twist drill

L. Screw extractor

M. External puller

N. Magnetic pick-up tool

O. Tubing cutter

P. Soldering iron

Q. Feeler gauge

R. Outside micrometer

S. Dial indicator

T. Spring tester

U. Pressure gauge (oil pressure)

V. Tachometer

INFORMATION SHEET

II. Types of screwdrivers (Transparency 4)

A. Common

B. Phillips head

C. Clutch head

D. Starting

E. Offset

III. Types of hammers

A. Ball peen

B. Soft

(NOTE: Types of soft hammers are lead, rawhide, plastic, brass, and rubber.)

IV. Types of pliers (Transparency 5)

A. Slip joint

B. Diagonal cutters

C. Needle nose

D. Side cutters

E. Lock grip

F. Snap ring

V. Types of wrenches (Transparencies 6, 7, and 8)

A. Open end

B. Adjustable

C. Box

D. Tubing

E. Hook spanner

F. Adjustable hook spanner

INFORMATION SHEET

G. Socket

1. Sliding "T" handle
2. Extension
3. Ratchet handle
4. Speed handle
5. Universal joint

(NOTE: The sockets may be six point, twelve point, or deepwell.)

H. Torque

I. Allen

J. Monkey

K. Pipe

L. Striking

VI. Types of cold chisels (Transparency 9)

A. Flat

B. Cape

C. Round nose

D. Diamond point

VII. Types of punches (Transparency 10)

A. Starting

B. Pin

C. Center

D. Aligning

VIII. Types of file teeth (Transparency 11)

A. Single cut

B. Double cut

INFORMATION SHEET

C. Rasp cut

D. Curved tooth

(NOTE: Files are made in numerous sizes and shapes. Common shapes are round, halfround, flat, and triangle.)

IX. Precautions for correct use of hacksaw

A. Teeth must point away from handle

B. Blade must be tightly stretched

C. Select blade with correct number of teeth per inch for material being cut

(NOTE: Two teeth should always be contacting the material being cut.)

D. Use sufficient pressure on the forward stroke

E. Use full length of blade on each stroke

X. Principle parts of twist drill

A. Shank

B. Flute

C. Cutting edge

XI. Ways to extract a screw

A. Screw extractor

B. Stud puller

C. Diamond point chisel

XII. Types of pullers (Transparency 12)

A. External

B. Press

C. Internal

XIII. Tools used for measuring speed

A. Revolution counter

B. Tachometer

C. Timing light (Stroboscope)

INFORMATION SHEET

XIV. Types of feeler gauges

A. Standard

B. Stepped

XV. Right and wrong use of tools (Transparencies 13, 14, 15, and 16)

A. Hammer

B. Hacksaw blade

C. Pliers

D. Cold chisel

E. Grinding screwdriver

F. Grinding flat cold chisel

G. Screwdriver

H. End wrench

I. Adjustable wrench

J. End wrench-adjustable wrench

K. Monkey wrench

L. File

M. File card-wrench extension

N. File handle-hammer handle

XVI. Types of micrometers (Transparency 17)

A. Outside

B. Inside

C. Depth

D. Vernier

XVII. Reading the micrometer (Transparencies 18, 19, and Overlay A)

A. Each numbered graduation on the sleeve represents one hundred thousandths of an inch (0.100")

INFORMATION SHEET

B. Each small graduation on the sleeve between the numbered graduations represents twenty-five thousandths of an inch (0.025")

C. Each graduation found on the thimble represents one thousandth of an inch (0.001")

D. Total reading is found by adding the three values

Example:	0.100	Number on the sleeve
	0.075	Small graduations on the sleeve
	0.015	Graduations on the thimble
	0.190	Micrometer reading

XVIII. Reading the vernier micrometer (Transparencies 19, 20, and Overlays A and B)

A. Each numbered graduation on the sleeve represents one hundred thousandths of an inch (0.100")

B. Each small graduation on the sleeve between the numbered graduations represents twenty-five thousandths of an inch (0.025")

C. Each graduation found on the thimble represents one thousandth of an inch (0.001")

D. Each line graduation found on top of the sleeve represents one ten-thousandth of an inch (0.0001")

E. Total reading is found by adding the four values

Example:	0.4000	Number on the sleeve
	0.0250	Small graduations on the sleeve
	0.0190	Graduations on the thimble
	0.0006	Vernier scale on top of sleeve
	0.4446	Vernier micrometer reading

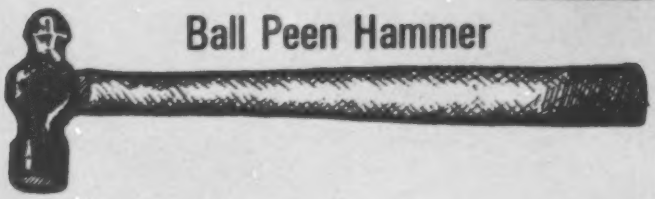
Basic Shop Tools

Common Screwdriver

Center Punch

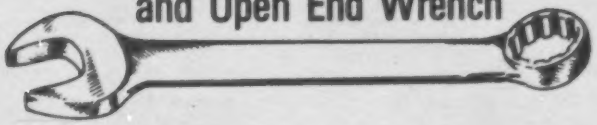
Flat Cold Chisel

Ball Peen Hammer



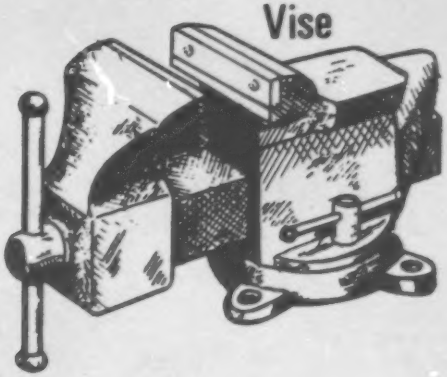
Flat File

Combination Box and Open End Wrench

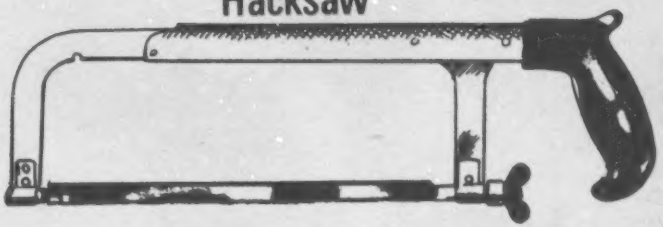


Slip Joint Pliers

Vise



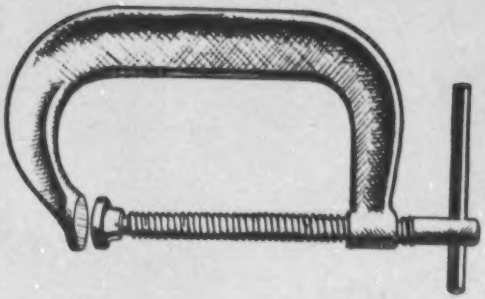
Hacksaw



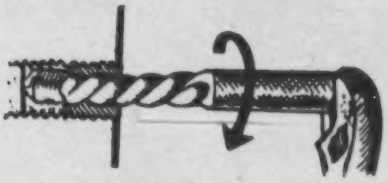
Basic Shop Tools

(Continued)

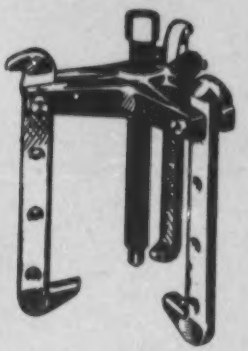
"C" Clamp



Screw Extractor



External Puller

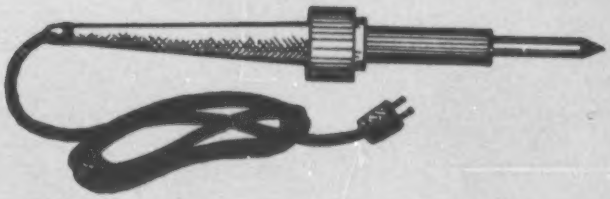


Twist Drill

Magnetic Pick-Up Tool

Tubing Cutter

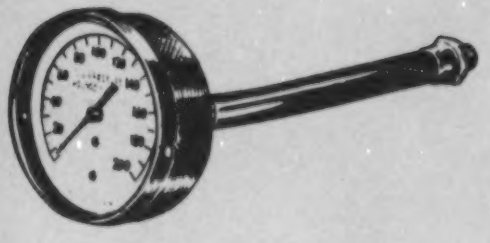
Soldering Iron



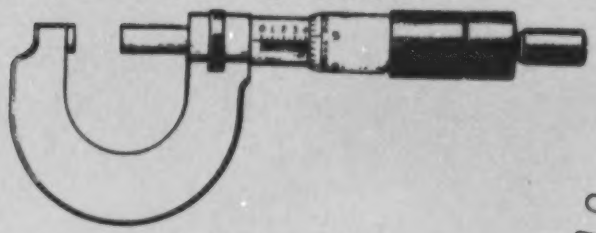
Basic Shop Tools

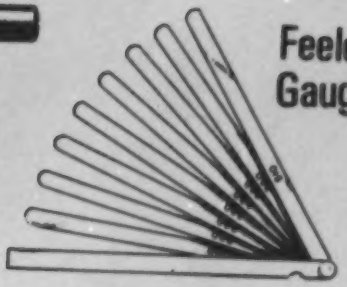
(Continued)

Pressure Gauge
(oil pressure)



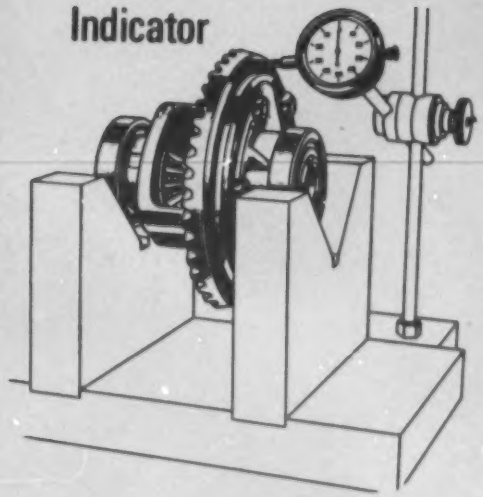
Outside Micrometer



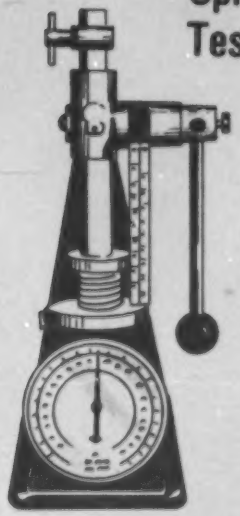


Feeler
Gauge

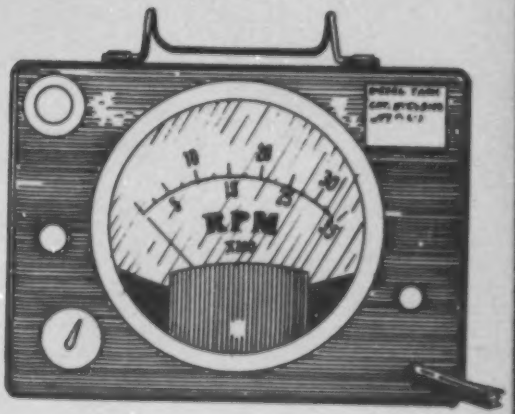
Dial
Indicator



Spring
Tester



Tachometer



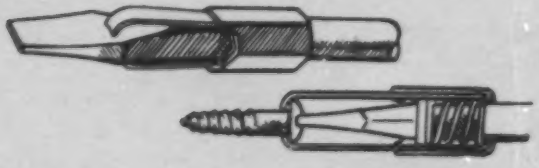
Types of Screwdrivers

Common

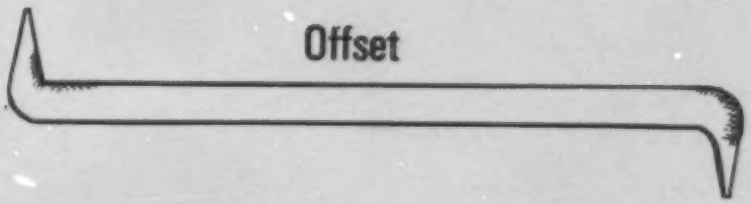
Phillips Head

Clutch Head

Starting Screwdriver
(Shown Holding Screw)

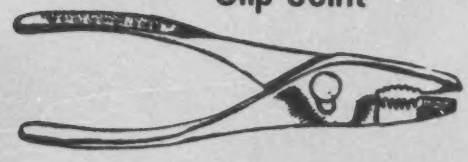


Offset



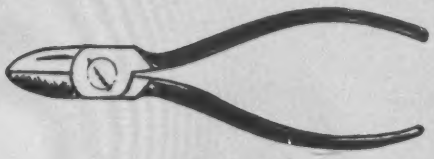
Types of Pliers

Slip Joint



Side Cutters

Diagonal Cutters

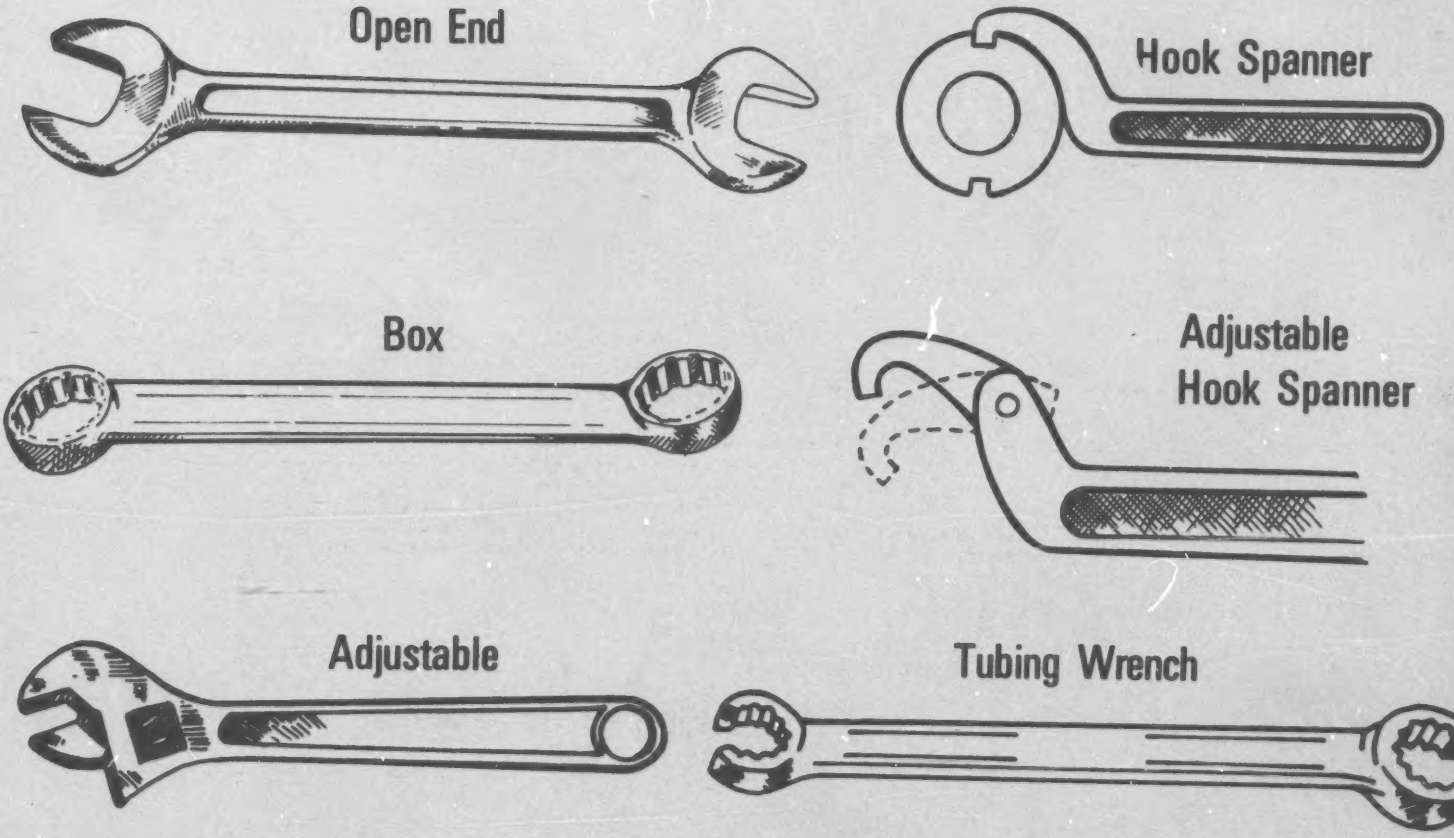


Lock Grip

Needle Nose

Snap Ring

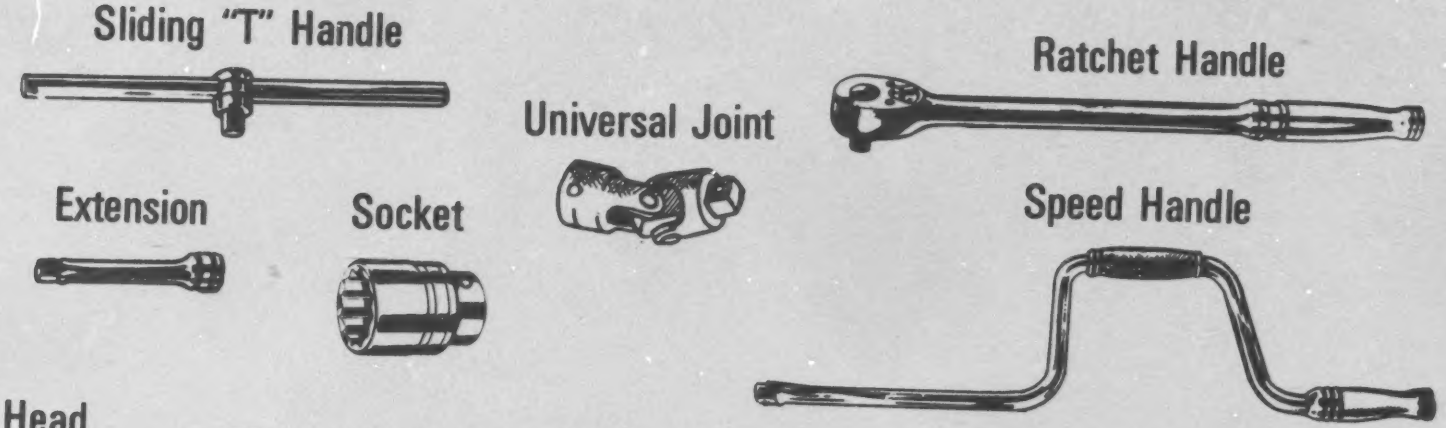
Types of Wrenches



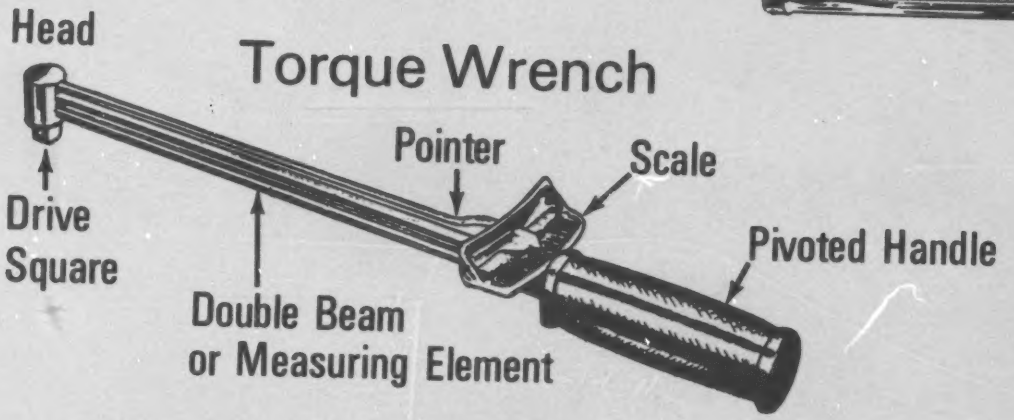
Types of Wrenches

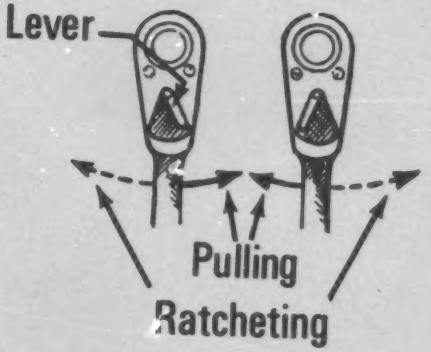
(Continued)

Socket Wrenches and Handles



Torque Wrench

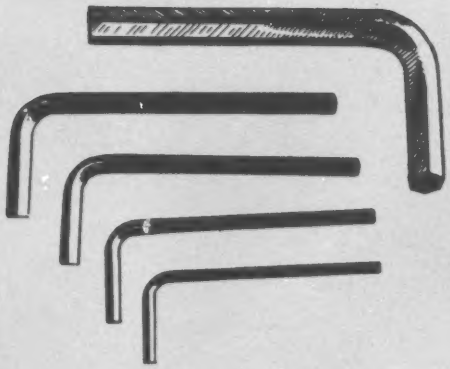




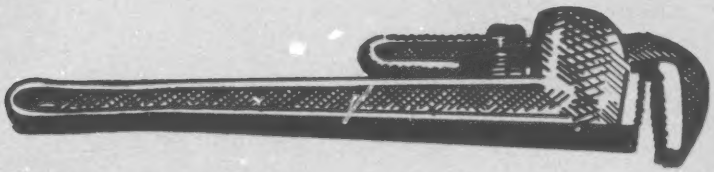
Types of Wrenches

(Continued)

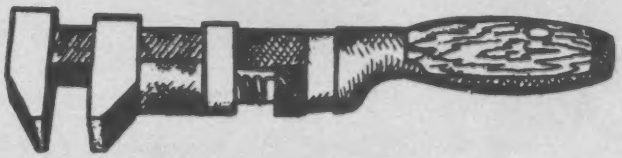
Allen



Pipe



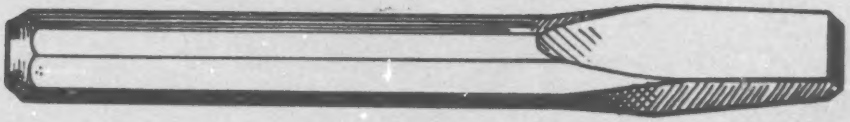
Monkey



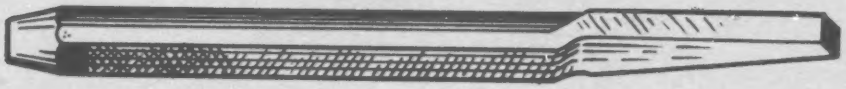
Striking

Types of Cold Chisels

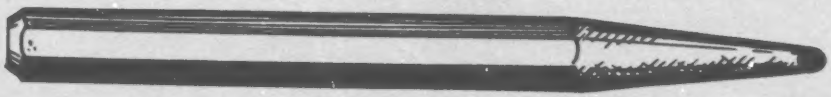
Flat Chisel



Cape Chisel



Round Nose Chisel



Diamond Point Chisel

Types of Punches

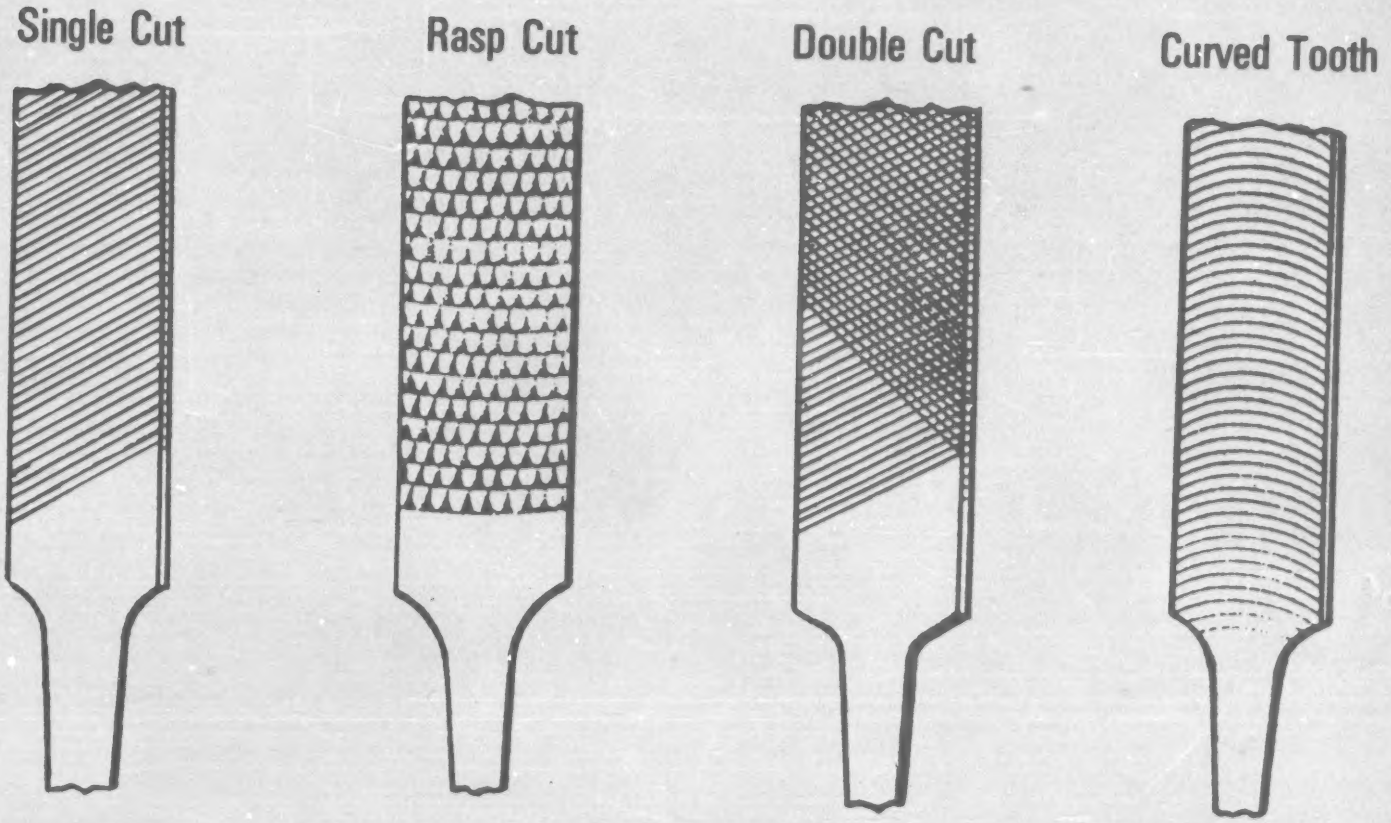
Starting Punch

Pin Punch

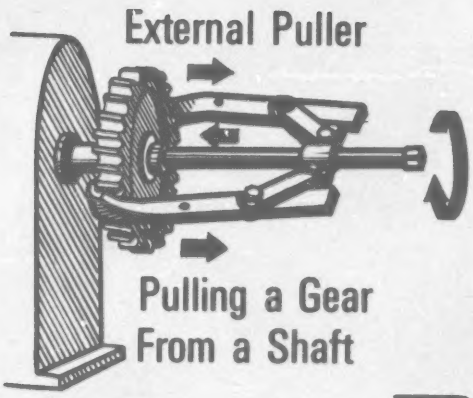
Center Punch

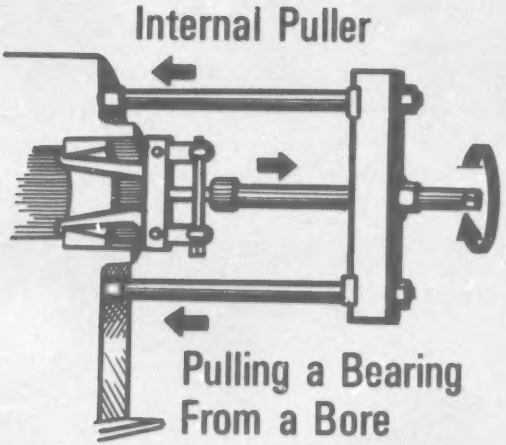
Aligning Punch

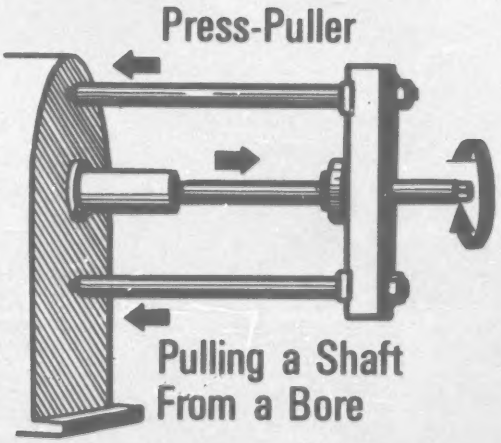
Types of File Teeth



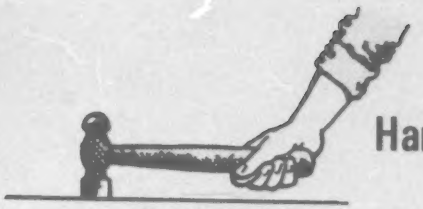
Types of Pullers







Right and Wrong Use of Tools

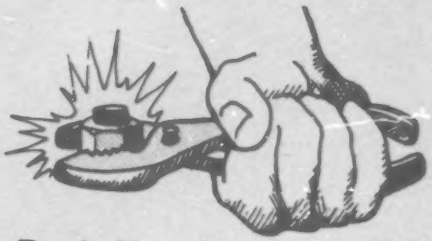


Right

Hammer

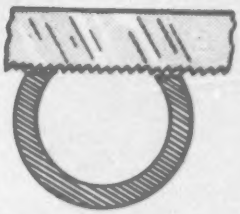
Wrong

Pliers

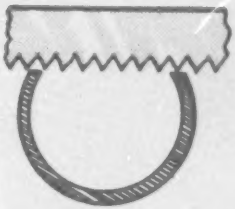


Don't Use Pliers on Nuts

Hacksaw Blade

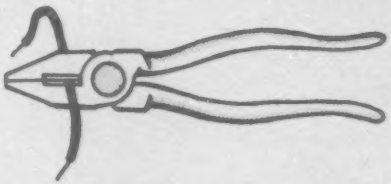


Right Blade



Wrong Blade

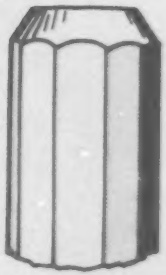
Side Cutters



Use Side Cutters to Cut Wire

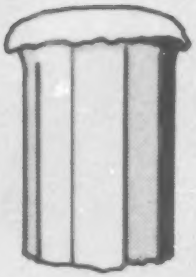
Right and Wrong Use of Tools

(Continued)



Right

Cold Chisel



Wrong

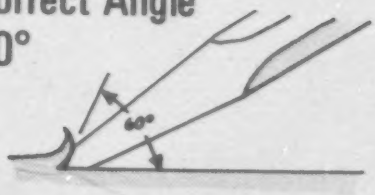
Right

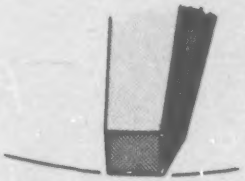
Grinding Screwdriver

Wrong

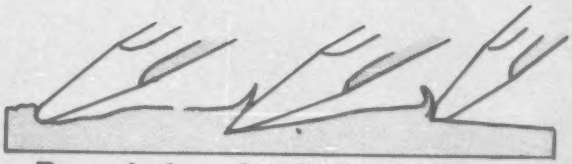
Grinding Flat Cold Chisel

Correct Angle 60°





Round Edge Slightly



Rounded and Dull

Angle is too Small

Angle is too Large

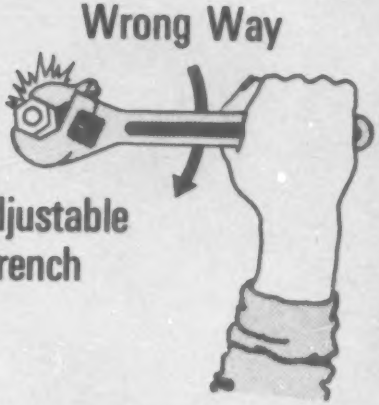
Screwdriver

Right

Wrong

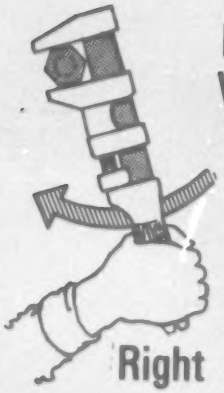
Right and Wrong Use of Tools

(Continued)



End Wrench -
Adjustable Wrench

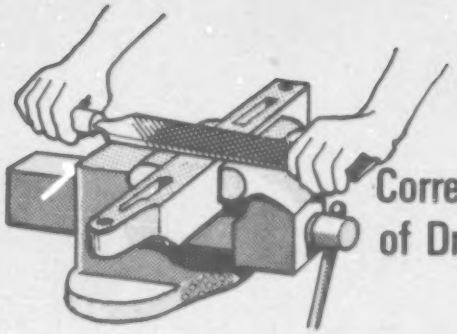
Wrong - Don't Pull on an Adjustable Wrench Until It has Been Tightened on the Nut



Monkey
Wrench

Right and Wrong Use of Tools

(Continued)



Correct Method of Draw-Filing

It is Dangerous to Use a File Without Handle

Wrong - Never Use a Bar or a Pipe on a Wrench

Correct Method of Cleaning a File

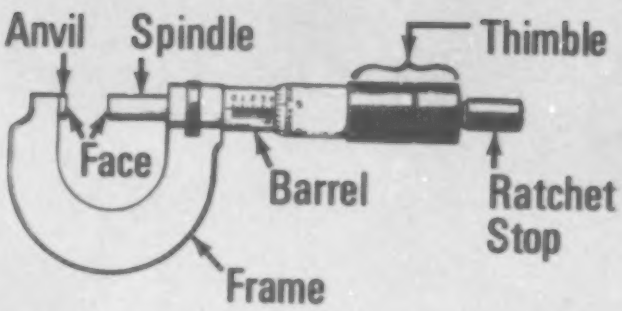
Correct Method of Tightening File Handle

This is Bad Practice

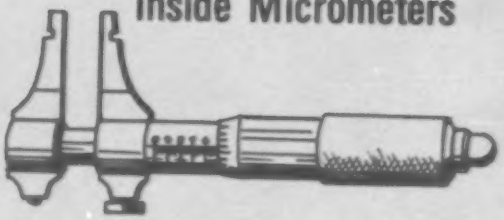
Incorrect Use of a Hammer

Types of Micrometers

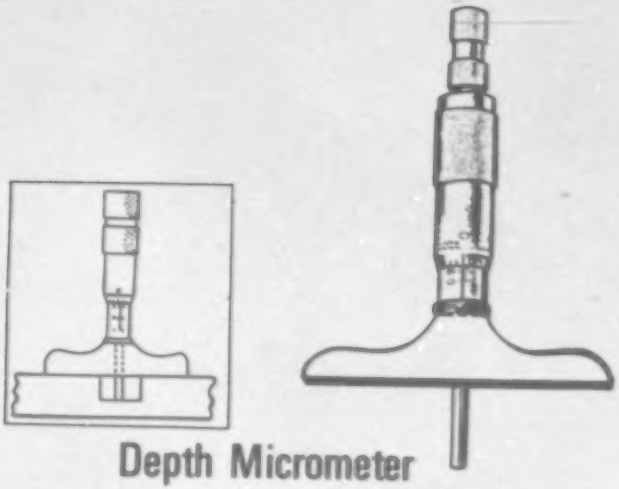
Outside Micrometer



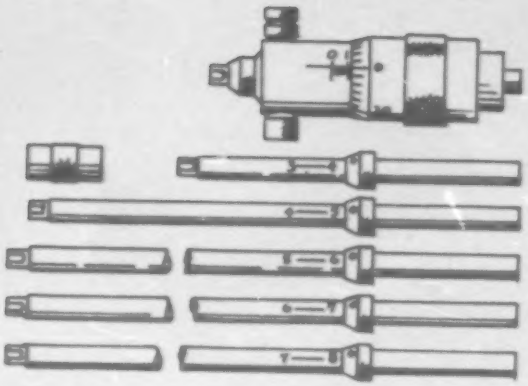
Inside Micrometers



Small Inside Diameter Micrometer

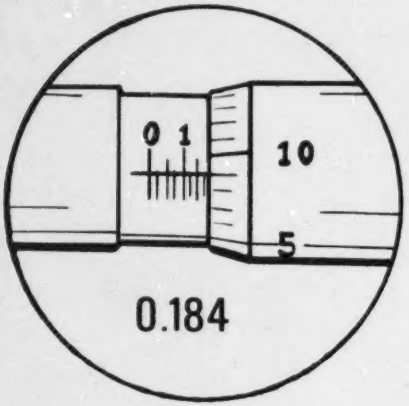


Depth Micrometer



Large Inside Diameter Micrometer

Reading a Micrometer



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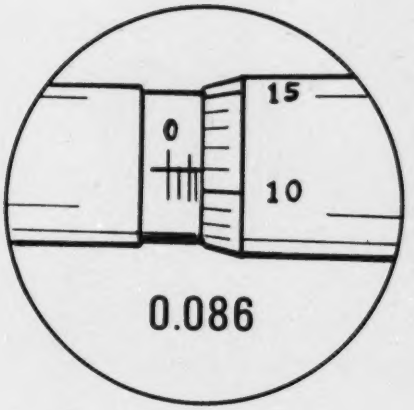

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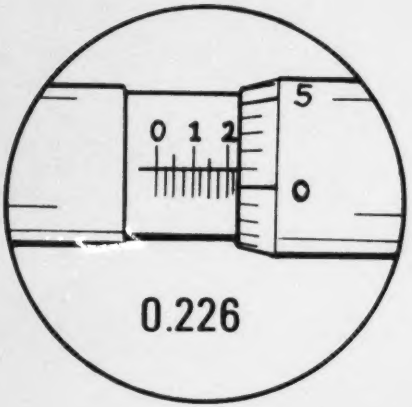

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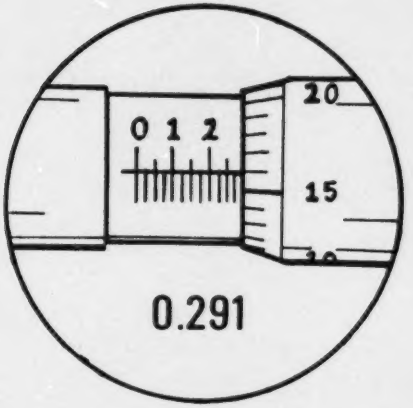

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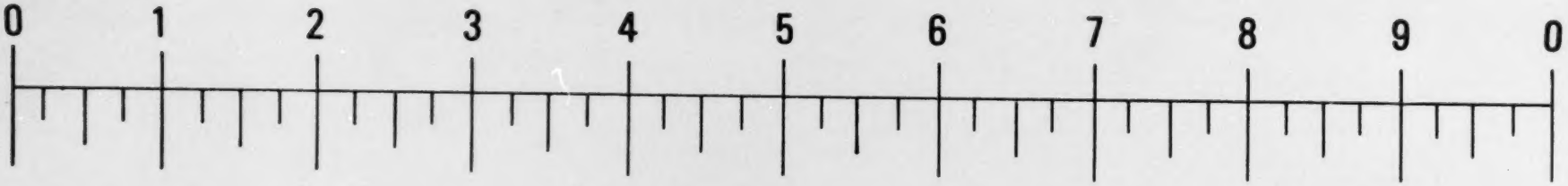
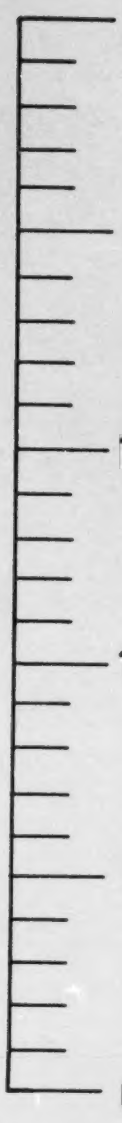


Sleeve Readings



Thimble Sleeve Readings

D - 85-A

Vernier Micrometer Readings

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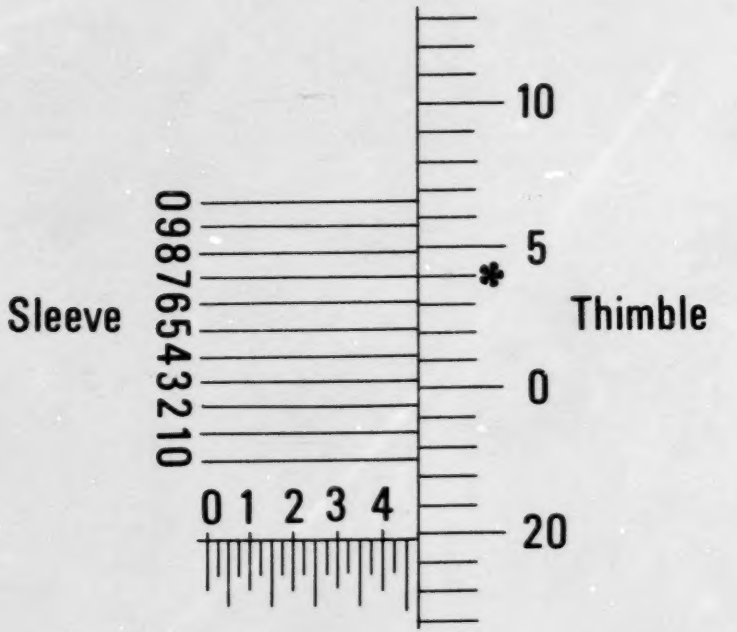

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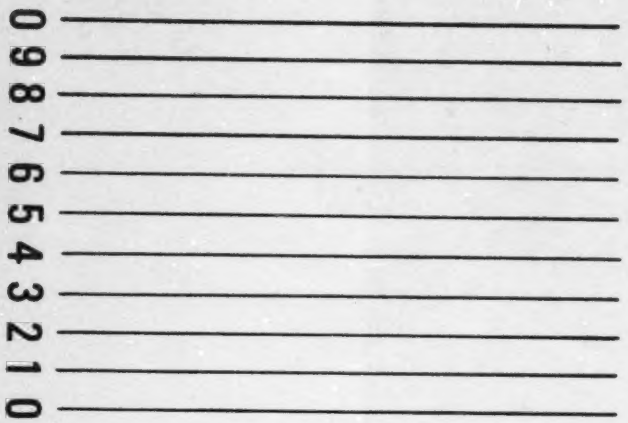

Vernier Sleeve Readings

BASIC SHOP TOOLS
UNIT III

ASSIGNMENT SHEET #1--READ THE MICROMETER SETTINGS

Read the micrometer settings below and write the correct answers in the blanks provided.

Answers

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
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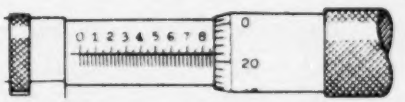
20. _____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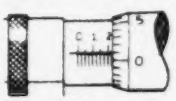
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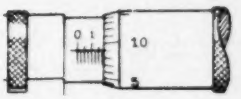
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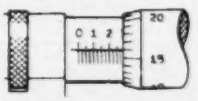
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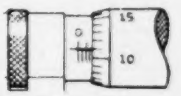
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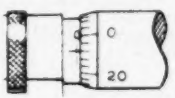
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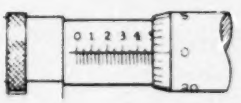
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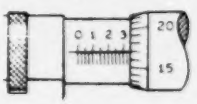
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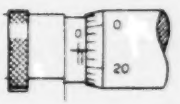
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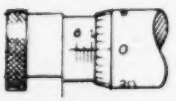
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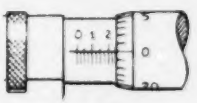
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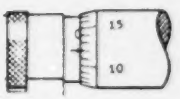
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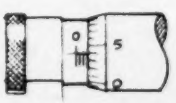
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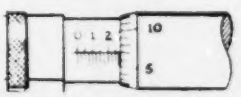
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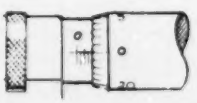
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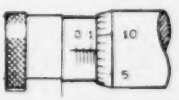
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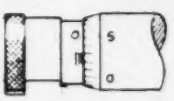
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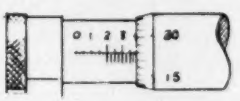
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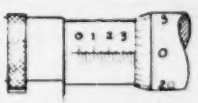
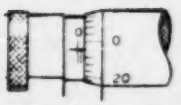

20.

ASSIGNMENT SHEET #1

21. _____
22. _____
23. _____
24. _____
25. _____



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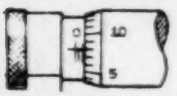

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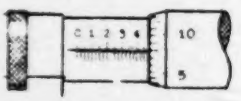

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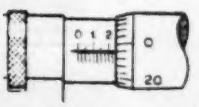

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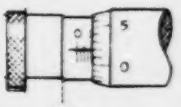


25.

BASIC SHOP TOOLS
UNIT III

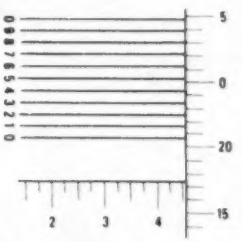
ASSIGNMENT SHEET #2--READ THE VERNIER MICROMETER SETTINGS

Read the vernier micrometer settings below and write the correct answers in the blanks provided.

Answers

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

1.



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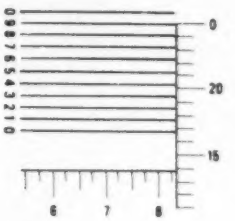

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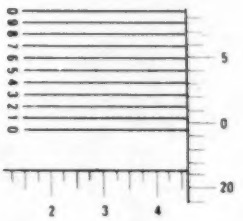

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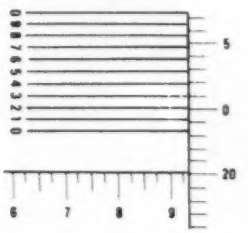

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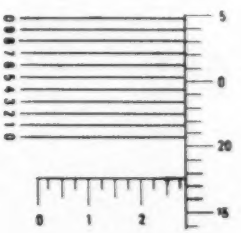

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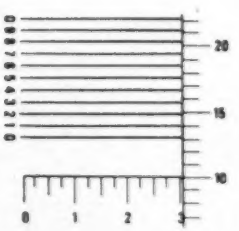

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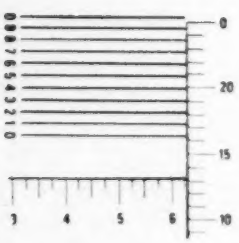

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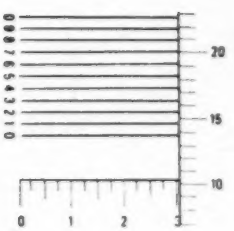

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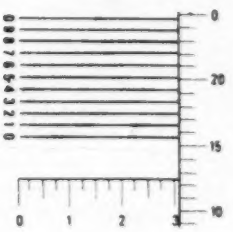

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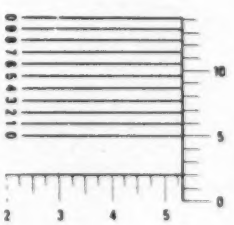


BASIC SHOP TOOLS
UNIT III

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. 0.871
2. 0.226
3. 0.184
4. 0.291
5. 0.086
6. 0.023
7. 0.500
8. 0.342
9. 0.047
10. 0.125
11. 0.613
12. 0.250
13. 0.012
14. 0.079
15. 0.282
16. 0.100
17. 0.133
18. 0.053
19. 0.393
20. 0.375
21. 0.049
22. 0.058
23. 0.483
24. 0.249
25. 0.102

Assignment Sheet #2

1. 0.4678
2. 0.8388
3. 0.4715
4. 0.9453
5. 0.2928
6. 0.3101
7. 0.6383
8. 0.3107
9. 0.3128
10. 0.5270

BASIC SHOP TOOLS
UNIT III

JOB SHEET #1--SHARPEN A TWIST DRILL

I. Tools and materials

A. Grinder

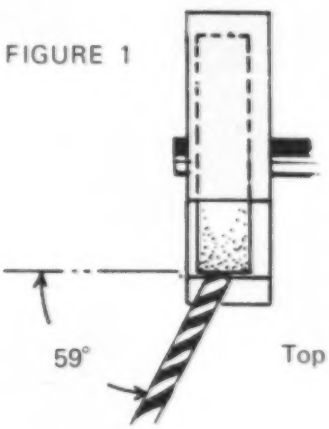
B. Twist drill

C. Container of water

II. Procedure

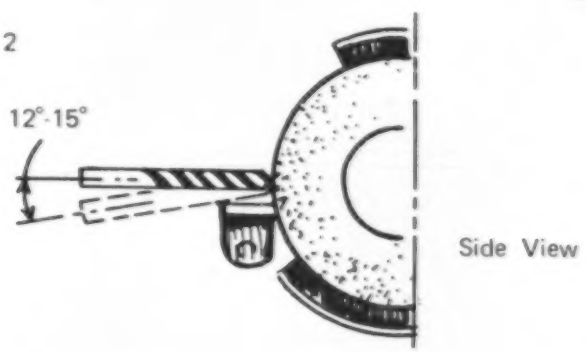
A. Place the drill point against the grinding wheel at approximately a 59° angle (Figure 1)

FIGURE 1



B. Using both hands, lower the shank, and raise the bit cutting point against the wheel (Figure 2)

FIGURE 2



JOB SHEET #1

C. Rotate the bit in a clockwise manner while grinding

D. Grind both lips in the same manner

E. Dip the point in water frequently to keep it cool

BASIC SHOP TOOLS
UNIT III

JOB SHEET #2--DRILL HOLES WITH A DRILL PRESS

I. Tools and materials

A. Small piece of flat metal

B. Drill press

C. Center punch

D. Hammer

E. Wooden block

F. Cutting oil

G. Clamp

H. Safety goggles

II. Procedure

A. Mark the hole with a center punch (Figure 1)

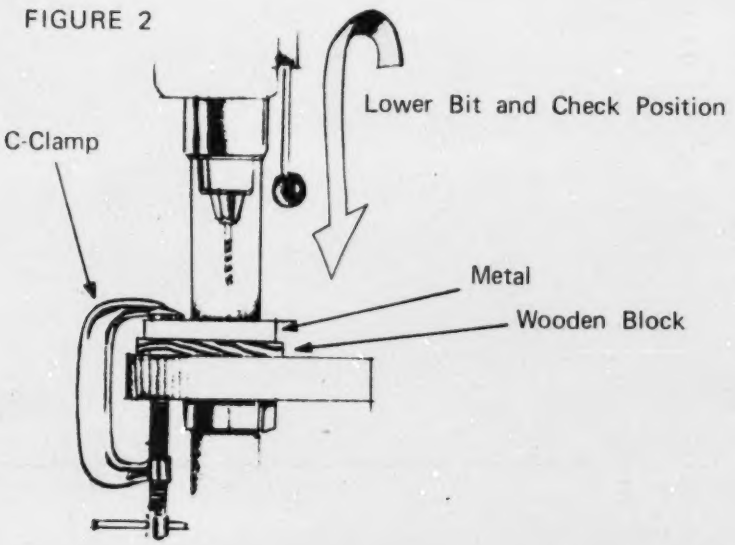
FIGURE 1

B. Place the metal on a wooden block

JOB SHEET #2

C. Clamp the metal being drilled securely to prevent it from spinning (Figure 2)

FIGURE 2



D. Feed the bit down to the metal and start drilling

(CAUTION: Select proper drill speed, if available.)

E. Raise the bit to see if you are drilling in the proper place

F. Continue drilling, using cutting oil on the drill bit two or three inches above the work

BASIC SHOP TOOLS
UNIT III

JOB SHEET #3--RESHAPE A COLD CHISEL

I. Tools and materials

A. Cold chisel

B. Grinder

C. Container of water

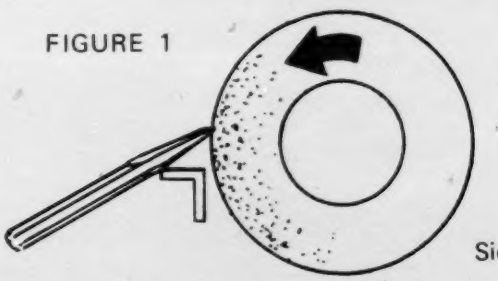
D. Eye protection

II. Procedure

A. Hold the chisel at a 65° to 70° angle with the handle pointing down (Figure 1)

(CAUTION: Check tool rest for proper adjustment.)

FIGURE 1



Side View

B. Move the point from side to side across the grinding wheel (Figure 2)

FIGURE 2

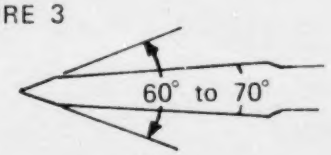
Top View

(NOTE: Dip the point in water frequently to keep it cool.)

JOB SHEET #3

C. Grind both sides of the cutting edge in the same manner (Figure 3)

FIGURE 3



D. Dip the point in water frequently to keep it cool

E. If the head has become mushroomed, it should be ground back into shape

BASIC SHOP TOOLS
UNIT III

JOB SHEET #4--CUT FLAT METAL WITH A COLD CHISEL

I. Tools and materials

A. Marker (oval or chalk)

B. Flat strip of metal

C. Chisel

D. Hammer

E. Vise

F. Eye protection

II. Procedure

A. Mark the metal

B. Place the metal in the vise with the cutting mark just above the jaws of the vise

C. Select proper size chisel and hammer

(NOTE: For larger size metal, use a larger chisel and hammer.)

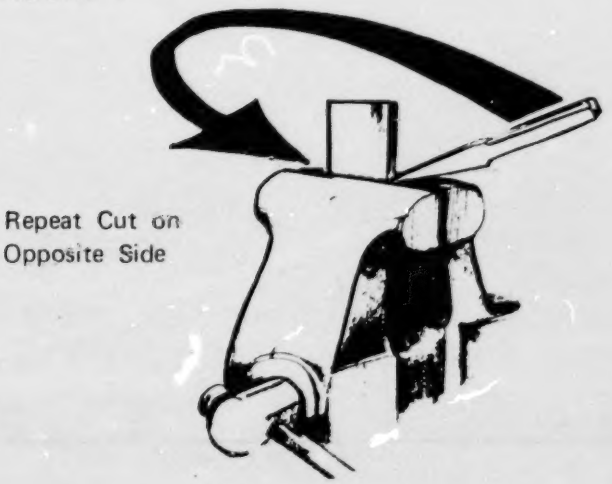
D. Place the chisel at side of the metal to start the shearing point

(NOTE: Drive the chisel with a hammer.)

JOB SHEET #4

E. Hold the chisel at approximately a 30° angle from line of cut (Figure 1)

FIGURE 1



F. Make cuts from each end of the metal to the center and on both sides

G. Bend metal back and forth until it breaks

BASIC SHOP TOOLS
UNIT III

JOB SHEET #5--DRESS A GRINDING WHEEL

I. Tools and materials

A. Grinding wheel

B. Dressing tool

C. Eye protection

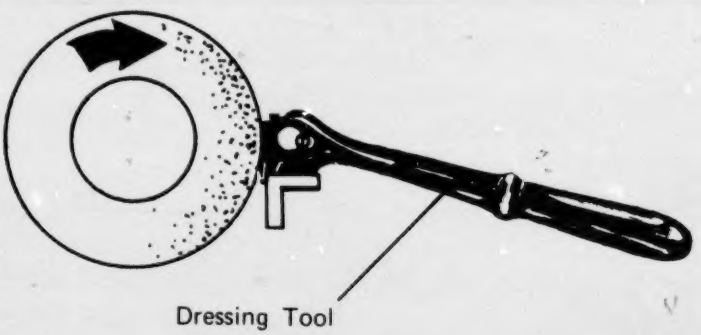
II. Procedure

A. Select the proper dressing tool

B. Set the dressing tool on the grinder tool rest and press it firmly against the wheel (Figure 1)

(NOTE: Use enough pressure on the tool to prevent sparks.)

FIGURE 1



C. Dress the grinder wheel with the tool until the edges are square with the sides

BASIC SHOP TOOLS
UNIT III

JOB SHEET #6--FIT A SCREWDRIVER

I. Tools and materials

A. Grinder

B. Screwdriver

C. Screw with head size equal to the width of the screwdriver's blade

D. Container of water

E. Eye protection

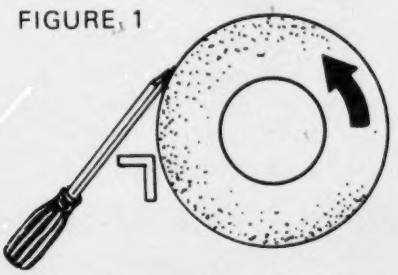
II. Procedure

A. Place screwdriver against the grinder wheel at a 90° angle to square the tip

B. Apply light pressure on blade, while grinding

C. Shape both faces of screwdriver (Figure 1)

FIGURE 1

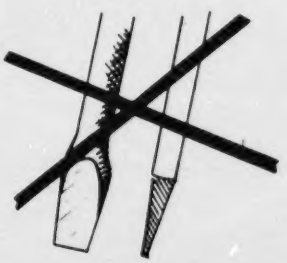


D. Use screw head to determine the extent of grinding desired

(NOTE: Do not round or sharpen the end. See Figure 2.)

FIGURE 2 Ground Right

Ground Wrong



E. Dip point in water frequently to keep it cool

BASIC SHOP TOOLS
UNIT III

JOB SHEET #7--REPLACE A HAMMER HANDLE

I. Tools and materials

A. Hammer with a broken handle

B. Hacksaw

C. Twist drill

D. Punch

E. Rasp

F. Handsaw

G. Soft faced hammer

H. Vise

(NOTE: Cover the jaws of the vise with sheet metal or use wood blocks to prevent damage to the hammer and handle.)

I. New handle

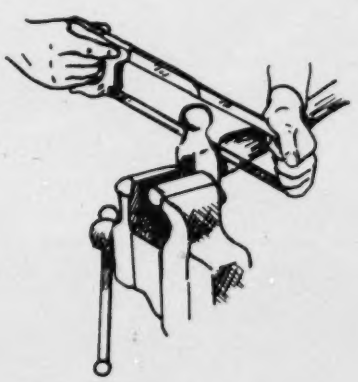
J. Small piece of wood for wedge

II. Procedure

A. Place the hammer head in the vise

B. Saw the broken handle close to the hammer head with a hacksaw (Figure 1)

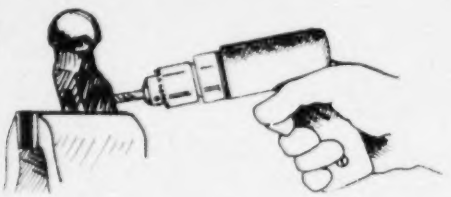
FIGURE 1



JOB SHEET #7

C. Remove the wood from the eye by first drilling with a twist drill and then punching the remainder out (Figure 2)

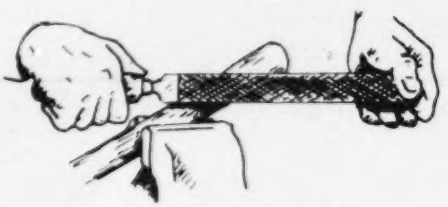
FIGURE 2



D. Place the new handle in the vise

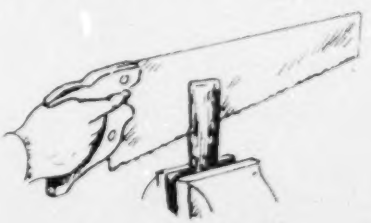
E. Work the new handle down to size with a rasp, trying the handle in the head frequently (Figure 3)

FIGURE 3



F. With a handsaw make a cut across the long diameter of the top of the handle to a distance of about 2/3 the depth of the eye (Figure 4)

FIGURE 4



G. Drive the handle firmly into place using a soft faced hammer (Figure 5)

FIGURE 5

H. Use a thin metal wedge and drive it tightly into the cut in the end of the handle

JOB SHEET #7

I. Place the hammer in the vise and use a hacksaw to cut off the handle and wedge extending through the head (Figure 6)

(NOTE: If steel wedges are used, the end of the handle need not be cut across the diameter, as the wedge can be driven into place after the handle has been cut off even with the head.)

FIGURE 6

BASIC SHOP TOOLS
UNIT III

JOB SHEET #8--TIN A SOLDERING IRON

I. Tools and materials

A. Soldering iron

B. File

C. Zinc chloride, sal ammoniac, or powdered rosin

D. Solder

E. Gas furnace or torch (if a nonelectric iron is being used)

F. Clean cloth

G. Eye protection

II. Procedure

A. Clean the four faces of the point with a file

(NOTE: This is necessary for removing rough spots from copper.)

B. Heat the iron until it will melt solder

C. Continue with one of the following three ways depending on materials available

(CAUTION: Provide adequate ventilation.)

1. Zinc chloride

a. Dip point quickly into and out of a jar of zinc chloride

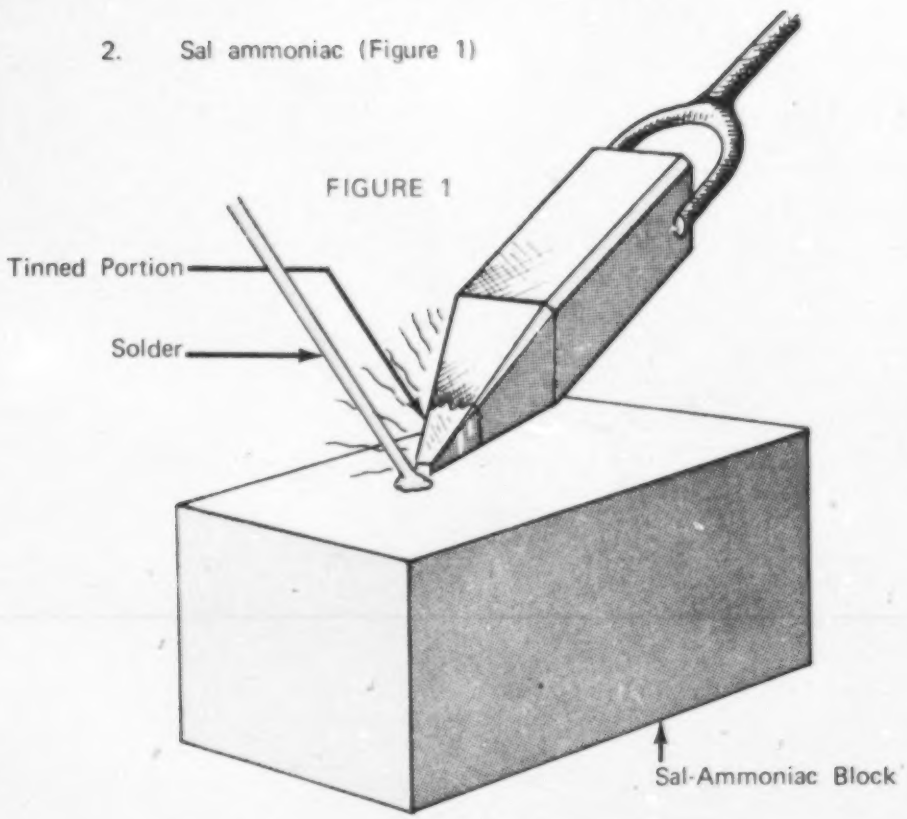
b. Melt solder on the faces

c. Wipe with a clean cloth to remove excess solder

JOB SHEET #8

2. Sal ammoniac (Figure 1)

FIGURE 1



a. Drop a few drops of solder on the sal ammoniac block

b. Rub the tip in the drops on the block

c. Remove excess solder by wiping the tip with a clean cloth

3. Rosin

a. Rub the tip in powdered rosin

b. Dip the tip in solder

c. Wipe with a clean cloth to remove excess solder

BASIC SHOP TOOLS
UNIT III

JOB SHEET #9--SOLDER A LAP JOINT

I. Tools and materials

A. Soldering iron

B. Solder

C. Flux

D. File

E. Water

F. Eye protection

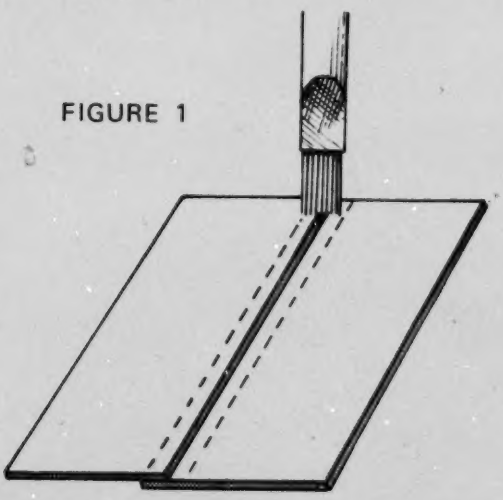
G. Two pieces of sheet metal, 2" x 6"

II. Procedure

A. Clean the area to be soldered

B. Apply flux (Figure 1)

FIGURE 1



C. Clean, heat, and tin the soldering iron

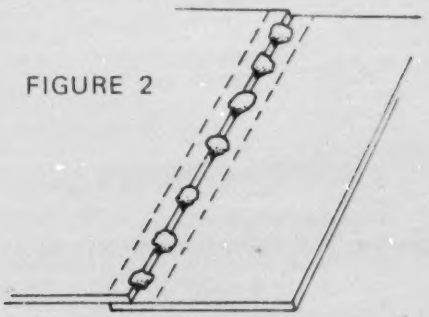
(NOTE: Never let it become red hot.)

JOB SHEET #9

D. Hold the seam together and tack it with small amounts of solder at several points (Figure 2)

(NOTE: Apply the solder directly in front of the soldering iron tip rather than on it.)

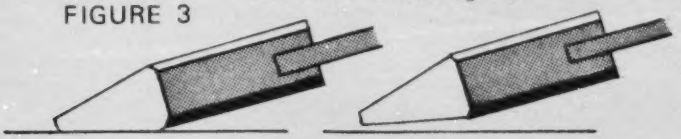
FIGURE 2



E. Return to the starting point and lay the soldering iron flat on the work (Figure 3)

Use of a Soldering Iron

FIGURE 3

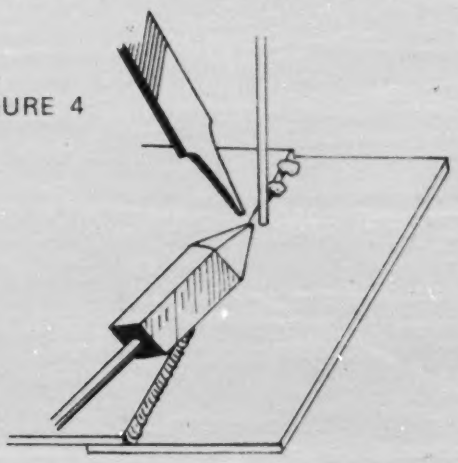


Proper Improper

F. With the seam pressed together with a file tang, start moving the soldering iron slowly toward the end of the joint as soon as the solder melts and begins to flow (Figure 4)

(NOTE: As the soldering iron advances, follow it with the file tang as soon as the solder hardens.)

FIGURE 4



JOB SHEET #9

G. Clean the seam with water

(NOTE: This only needs to be done if an acid flux such as zinc chloride, sal ammoniac, or other acid is used. The joint and the metal touched by the flux will turn black if this is not done.)

BASIC SHOP TOOLS
UNIT III

JOB SHEET #10--CHECK A TORQUE WRENCH FOR ACCURACY

I. Tools and materials

A. Torque wrench

B. Vise

C. "Known" weight

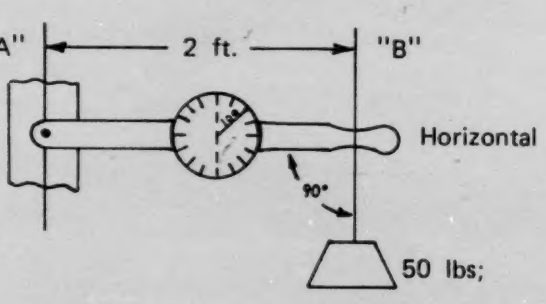
D. Strong cord

II. Procedure

A. Hang torque wrench on a fixed nut or secure in a vise (Figure 1)

FIGURE 1

A=Center Line of Nut
B=Point of Suspension



B. Set the indicator to "O"

C. Hang a known weight from the wrench handle at any known distance from the center of the nut (Figure 1)

D. Multiply the weight times the distance from A to B (Figure 1)

E. Compare the answer to the indicator reading

Example: In figure 1, 50 pounds x 2 feet = 100 foot pounds

BASIC SHOP TOOLS
UNIT III

JOB SHEET #11--DRAW FILE A FLAT SURFACE

I. Tools and materials

A. File handle

B. Machinist's file

(NOTE: Machinist's file has double cut teeth for cutting in both directions.)

C. Vise

D. Stock to be draw filed

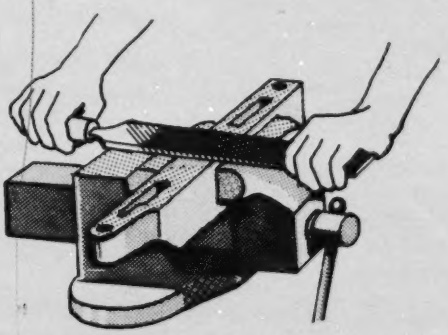
II. Procedure

A. Secure stock to be filed in vise

B. Equip file with a tight fitting handle

C. Draw the file crosswise over the work with a light pressure (Figure 1)

FIGURE 1



D. Apply enough pressure to keep file cutting in both directions

BASIC SHOP TOOLS
UNIT III

JOB SHEET #12--DRAW A TWIST DRILL TO CORRECT CENTER

I. Tools and materials

A. Electric drill, 1/2" chuck

B. High speed twist drill

C. Center punch

D. Ball peen hammer

E. Stock to be drilled

F. Lubricating oil

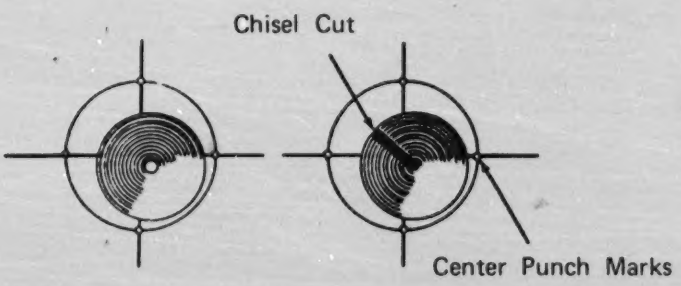
II. Procedure

A. Make a center punch mark on stock

B. Enlarge the center punch mark slightly and remove before whole point has entered the material

C. Make a chisel cut to side to which the drill should be drawn (Figure 1)

FIGURE 1



How to Draw the Drill Back to Correct Center

D. Make another punch mark for new center

E. Repeat step B above

BASIC SHOP TOOLS
UNIT III

JOB SHEET #13--USE THE OUTSIDE MICROMETER

I. Tools and materials

A. 0" - 1.000" outside micrometer

B. 1.000" - 2.000" outside micrometer

C. Lathe or vise

D. New fractional drill bits, assortment of 5

E. New letter size drill bits, assortment of 5

F. Pieces of metal such as cold rolled stock, machined parts, hardened dowels, assortment of 5

(NOTE: All workpieces should be numbered or lettered for reference.)

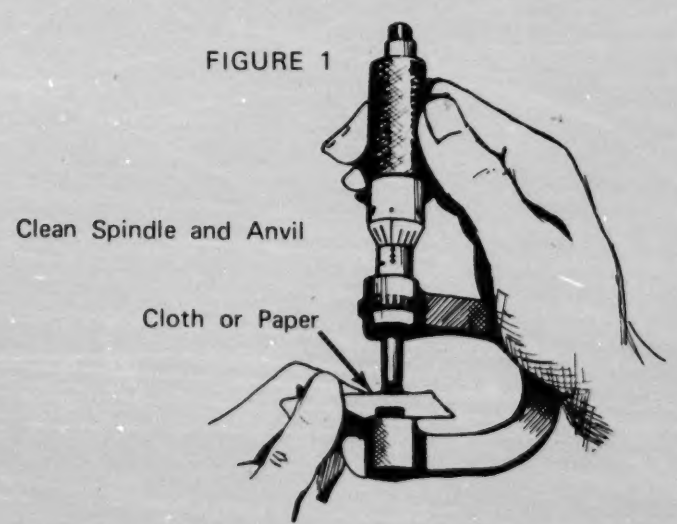
II. Procedure

A. Select workpieces that are clean and free of burrs, nicks, or dents

B. Select the proper size micrometer for the workpiece

C. Clean the spindle and anvil of the micrometer (Figure 1)

FIGURE 1



JOB SHEET #13

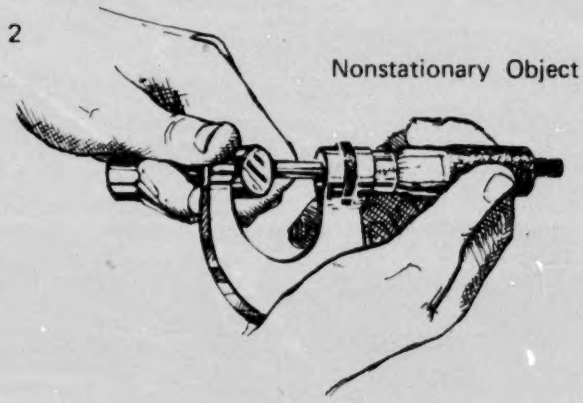
D. Check the micrometer at zero reference

E. Hold the micrometer according to the type of workpiece

1. Hold the micrometer in the right hand and the workpiece in the left hand to measure a nonstationary object (Figure 2)

FIGURE 2

Nonstationary Object



2. Hold the micrometer in both hands to measure a stationary object (Figure 3)

FIGURE 3

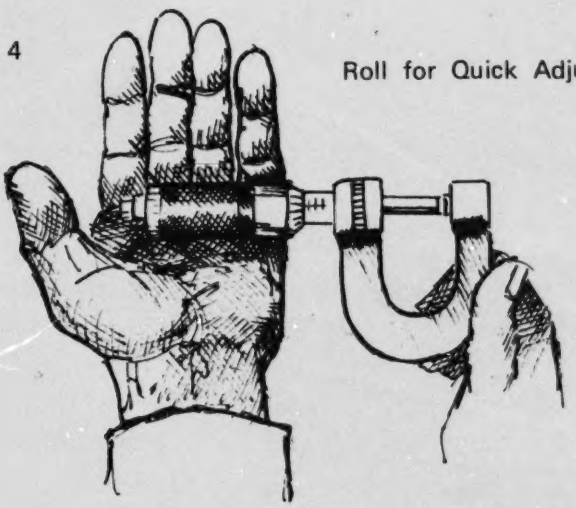
Stationary Object

JOB SHEET #13

(NOTE: Roll micrometer along palm of hand or forearm for quick adjustment. See Figure 4.)

FIGURE 4

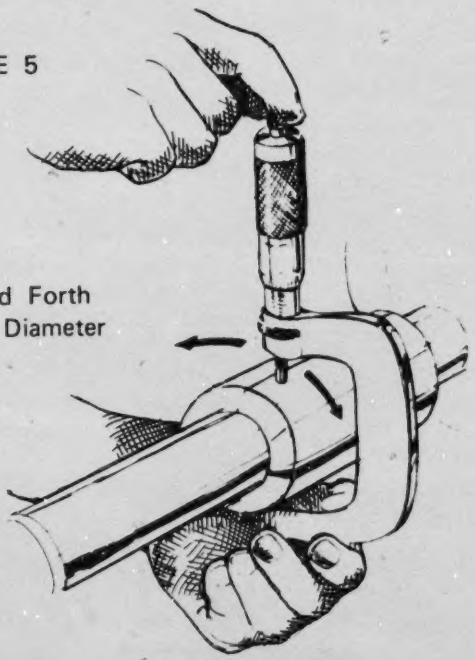
Roll for Quick Adjustment



F. Place the micrometer directly over the center of the workpiece to be measured (Figure 5)

FIGURE 5

Work Back and Forth
to Find True Diameter



JOB SHEET #13

G. Turn the thimble of the micrometer until the anvil and spindle contact the workpiece

H. Hold the anvil steady and move the spindle lightly over the workpiece to locate the true centerline (Figure 5)

I. Use ratchet stop or light sense of feel to determine exact measurement

J. Observe micrometer readings

(NOTE: Spindle lock can be turned to hold measurement if micrometer must be removed from workpiece. Spindle must be unlocked before resetting to a new measurement.)

K. List the readings according to the letter or number on the workpiece

L. Return the micrometer to its correct storage

(NOTE: The spindle and anvil of the micrometer should be left open when stored.)

M. Hand in the listed readings to the instructor for evaluation

BASIC SHOP TOOLS
UNIT III

JOB SHEET #14--USE THE VERNIER MICROMETER

I. Tools and materials

A. 0" - 1.0000" vernier micrometer

B. 1.0000" - 2.0000" vernier micrometer

C. Lathe or vise

D. New number drill bits, assortment of 5

E. New fractional drill bits, assortment of 5

F. Pieces of metal such as cold rolled stock, machined parts, hardened dowels, assortment of 5

(NOTE: All workpieces should be numbered or lettered for reference.)

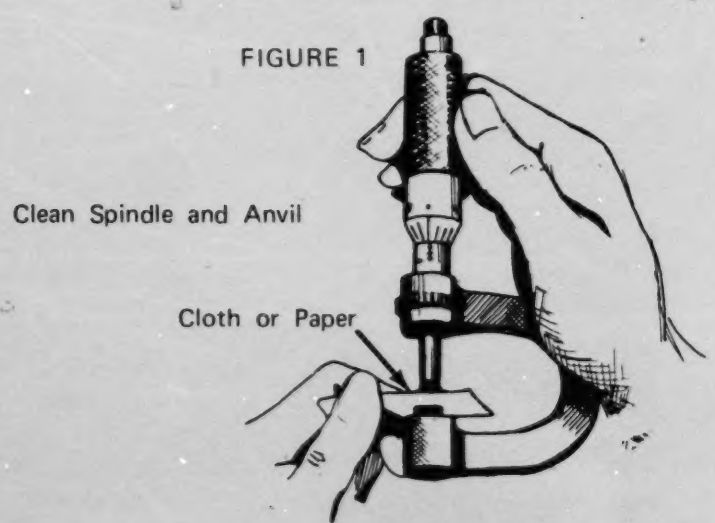
II. Procedure

A. Select workpieces that are clean and free of burrs, nicks, or dents

B. Select the proper size micrometer for the workpiece

C. Clean the spindle and anvil of the micrometer (Figure 1)

FIGURE 1



JOB SHEET #14

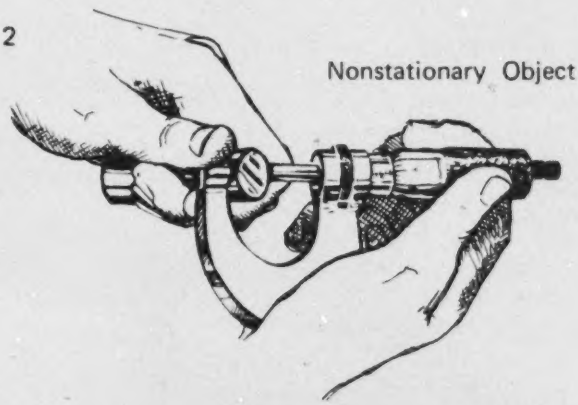
D. Check the micrometer at zero reference

E. Hold the micrometer according to the type of workpiece

1. Hold the micrometer in the right hand and the workpiece in the left hand to measure a nonstationary object (Figure 2)

FIGURE 2

Nonstationary Object



2. Hold the micrometer in both hands to measure a stationary object (Figure 3)

FIGURE 3

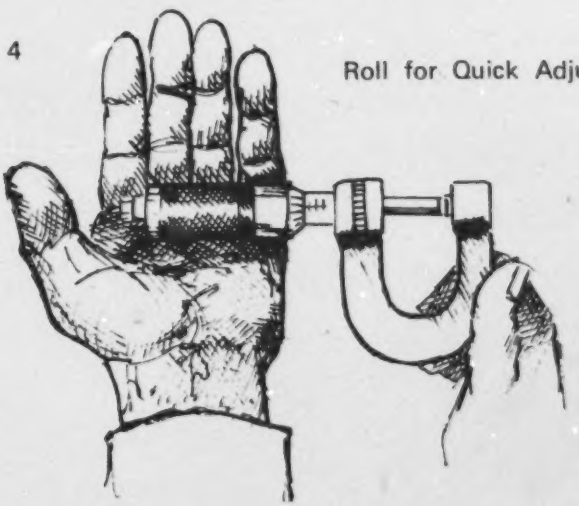
Stationary Object

JOB SHEET #14

(NOTE: Roll micrometer along palm of hand or forearm for quick adjustment. See Figure 4.)

FIGURE 4

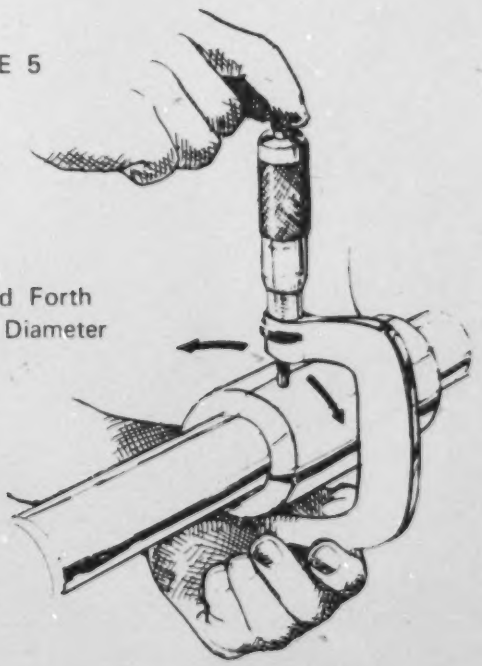
Roll for Quick Adjustment



F. Place the micrometer directly over the center of the workpiece to be measured (Figure 5)

FIGURE 5

Work Back and Forth
to Find True Diameter



JOB SHEET #14

G. Turn the thimble of the micrometer until the anvil and spindle contact the workpiece

H. Hold the anvil steady and move the spindle lightly over the workpiece to locate the true centerline (Figure 5)

I. Use ratchet stop or light sense of feel to determine exact measurement

J. Observe micrometer readings

(NOTE: Spindle lock can be turned to hold measurement if micrometer must be removed from workpiece. Spindle must be unlocked before resetting to a new measurement.)

K. List the readings according to the letter or number on the workpiece

L. Return the micrometer to its correct storage

(NOTE: The spindle and anvil of the micrometer should be left open when stored.)

M. Hand in the listed readings to the instructor for evaluation

BASIC SHOP TOOLS
UNIT III

JOB SHEET #15--CUT EXTERNAL THREADS

I. Tools and materials

A. Die

B. Die stock (handle)

C. Vise

D. Flat tile

E. Cutting oil

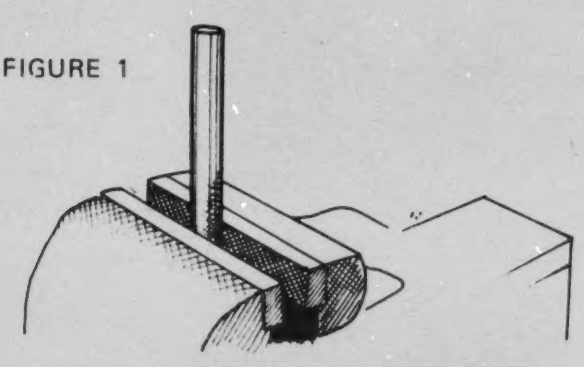
F. Rod or stock to be threaded

G. Shop towel

II. Procedure

A. Place rod in vise (Figure 1)

FIGURE 1



B. Chamfer end of rod with file

C. Lubricate end of rod with cutting oil

D. Place die in die stock and secure

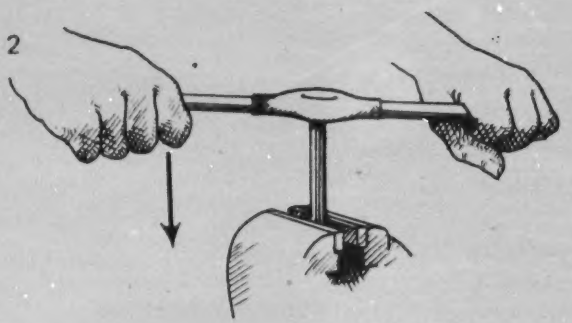
E. Place die on top of rod with taper facing down

F. Start die straight on the rod

JOB SHEET #15

G. Press down evenly and turn the die (Figure 2)

FIGURE 2



H. Apply a few drops of cutting oil while turning the die

I. Check die often for squareness

J. Turn the die one turn clockwise and then 1/4 to 1/2 a turn counterclockwise to break the chip

K. Continue this procedure until the desired amount of threads have been cut

L. Remove die by turning counterclockwise

M. Hold onto the die stock firmly while removing it so as not to drop it when it comes to the end of the threads

N. Clean threads with a brush

(CAUTION: Do not use compressed air for cleaning.)

O. Clean tools and put them away

BASIC SHOP TOOLS
UNIT III

JOB SHEET #16--CUT INTERNAL THREADS

I. Tools and materials

A. Tap

B. Tap wrench

C. Drill motor

D. Tap drill

E. Vise

F. Cutting oil

G. Stock to be drilled and threaded

II. Procedure

A. Place workpiece in vise

B. Drill hole top proper size

C. Use the chart below to select the proper tap drill

Sizes	Threads Per Inch	Outside Diameter of Screw	Tap Drill Sizes	Decimal Equivalent of Drill
1	64	073	53	0.0595
2	56	086	50	0.0700
3	48	099	46	0.0810
4	40	112	43	0.0890
5	40	125	38	0.1015
6	32	138	33	0.1130
8	32	164	29	0.1360
10	24	190	25	0.1495
12	24	216	16	0.1770
1/4	20	250	7	0.2010
5/16	18	3125	F	0.2570
3/8	16	375	5/16	0.3125
7/16	14	4375	U	0.3680
1/2	13	500	27/64	0.4219
9/16	12	5625	31/64	0.4843
5/8	11	625	17/32	0.5312
3/4	10	750	21/32	0.6562
7/8	9	875	49/64	0.7656

JOB SHEET #16

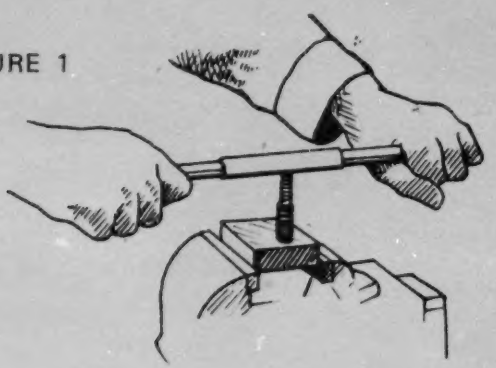
D. Place tap in tap wrench

E. Place tap in hole and keep the tap as straight as possible

F. Apply cutting oil to tap

G. Press down on tap wrench with equal pressure on both sides (Figure 1)

FIGURE 1



H. Make two complete turns with tap

I. Check to see that the tap is straight

J. If tap is not straight, remove it and restart

(NOTE: A slight amount of pressure will be required to get the tap to start straight.)

K. Tap the hole by turning the tap wrench clockwise 1/2 a turn then counterclockwise a 1/4 of a turn

L. After the hole is tapped, remove the tap by turning the wrench counterclockwise

(NOTE: Hold on to the tap wrench to prevent it from falling on the floor.)

M. Clean tools and put away

N. Have the instructor inspect

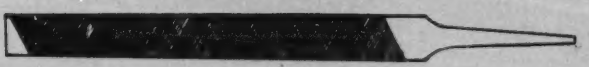
BASIC SHOP TOOLS
UNIT III

NAME _____

TEST

1. Identify the basic shop tools.

a. _____



b. _____

c. _____

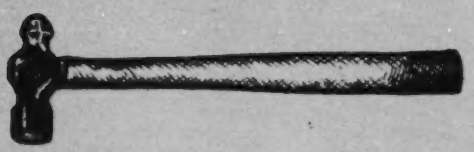
d. _____

e. _____

f. _____

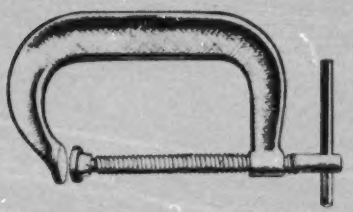
g. _____

h. _____

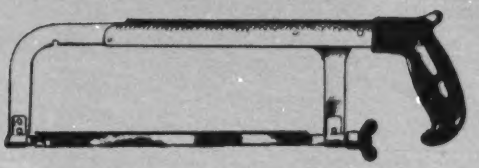


i. _____

j. _____

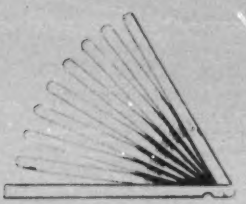


k. _____

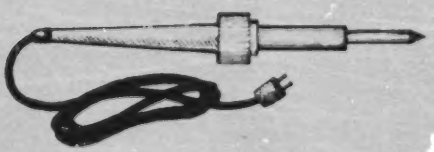


l. _____

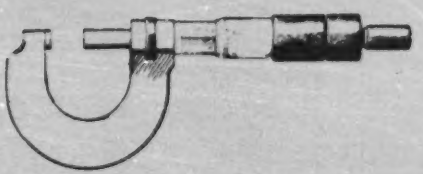
m. _____



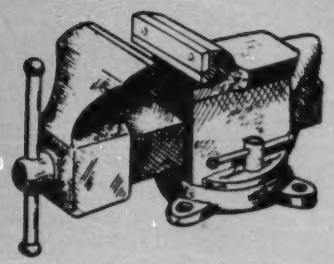
n. _____



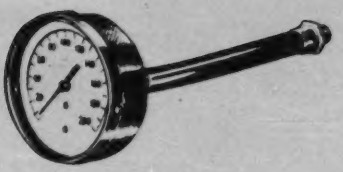
o. _____



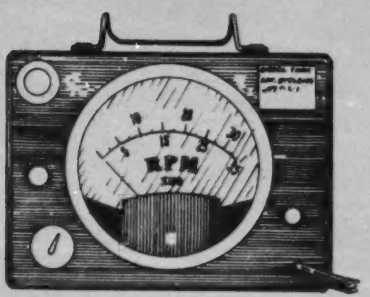
p. _____



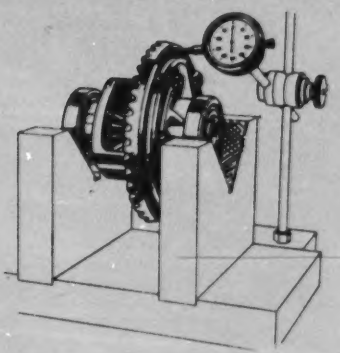
q. _____



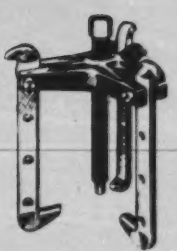
r. _____



s. _____



t. _____



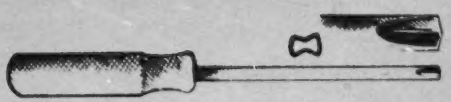
u. _____

v. _____

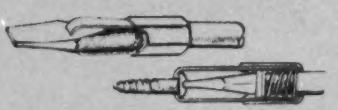
2. Identify types of screwdrivers.

a. _____

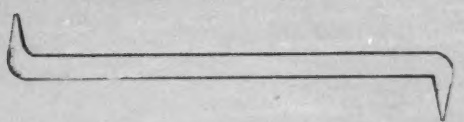
b. _____



c. _____



d. _____



e. _____

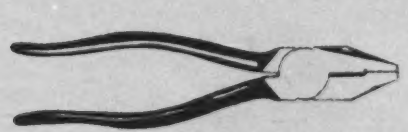
3. Name two types of hammers.

a.

b.

4. Identify the types of pliers.

a. _____

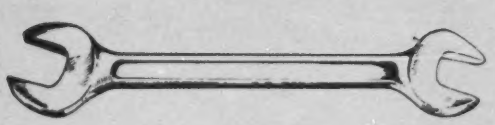


b. _____

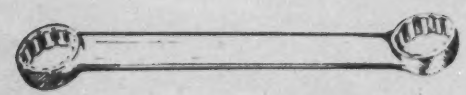
c. _____ d. _____

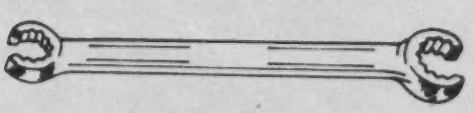
e. _____ f. _____

5. Identify the types of wrenches.



a. _____ b. _____



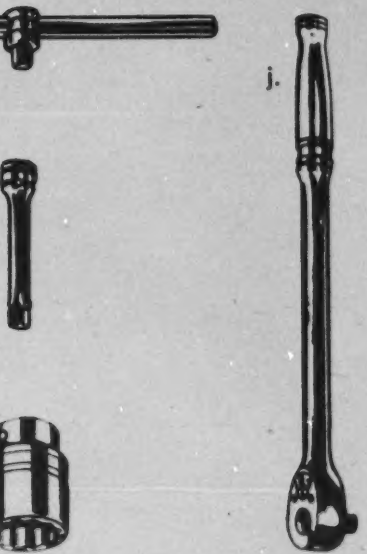


c. _____ d. _____

e. _____

f. _____

g.



j.

k.

h.

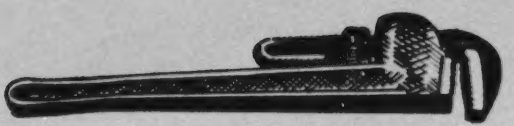
l.

i.

g. _____ h. _____

i. _____ j. _____

k. _____ l. _____

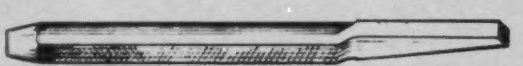


m. _____ n. _____

o. _____ p. _____

q. _____

6. Identify the types of cold chisels.



a. _____ b. _____

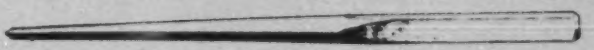
c. _____ d. _____

7. Identify the types of punches.

a. _____

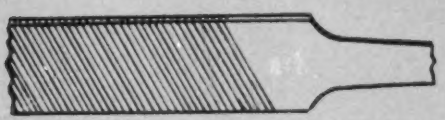
b. _____

c. _____

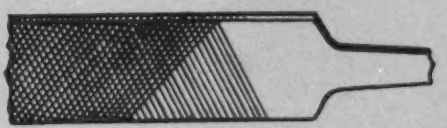


d. _____

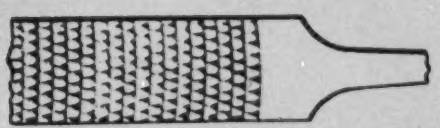
8. Identify the types of file teeth.



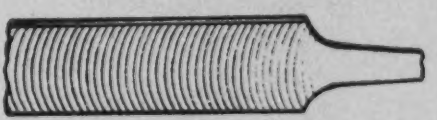
a. _____



b. _____



c. _____



d. _____

9. Name three precautions for correct use of the hacksaw.

a.

b.

c.

10. Name three principle parts of a twist drill.

a.

b.

c.

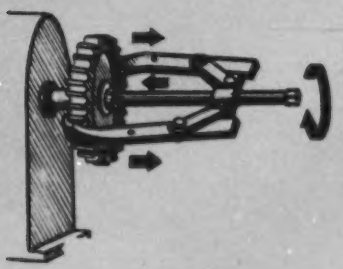
11. Name three ways to extract a screw.

a.

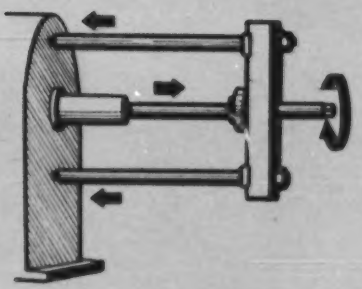
b.

c.

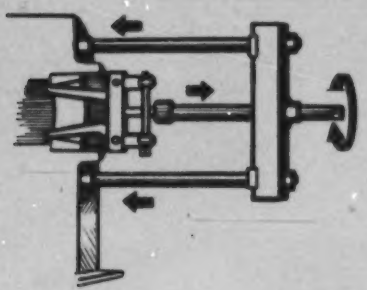
12. Identify three types of pullers.



a. _____



b. _____



c. _____

13. Name three shop tools used for measuring speed.

a.

b.

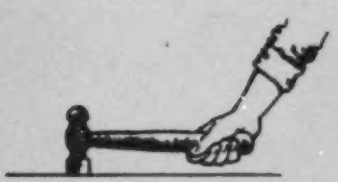
c.

14. List two types of feeler gauges.

a.

b.

15. Distinguish between correct and incorrect methods of using and maintaining basic shop tools by placing an "X" next to the illustrations of correct methods.

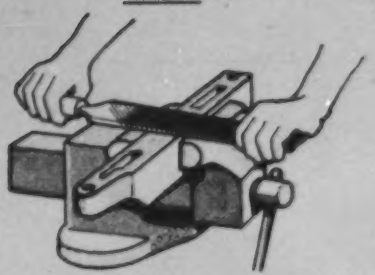


_____a.

_____b.

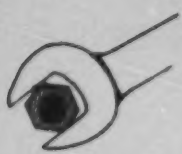
____c.

____d.



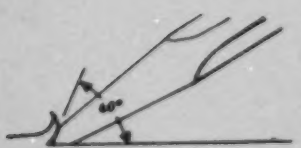
____e.

____f.

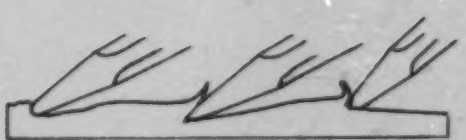


____g.

____h.

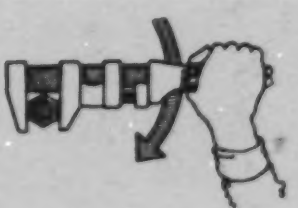


____i.



____j.

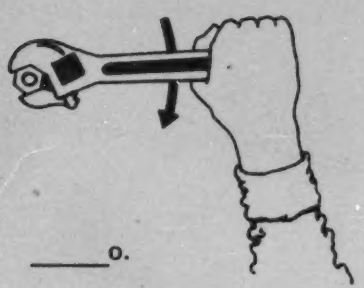
____k.



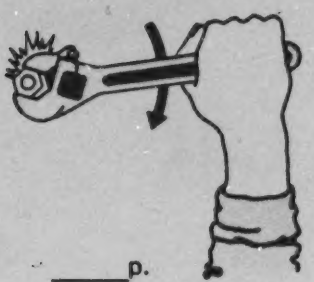
____l.

_____m.

_____n.

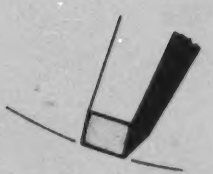


_____o.

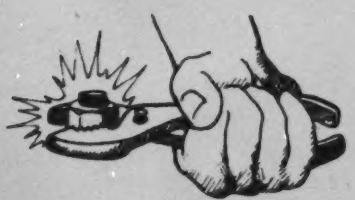


_____p.

_____q.



_____r.

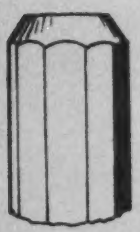


_____s.

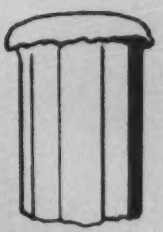
_____t.

_____u.

_____v.

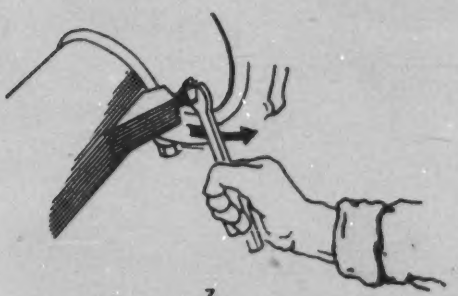


_____w.

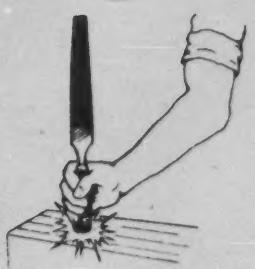


_____x.

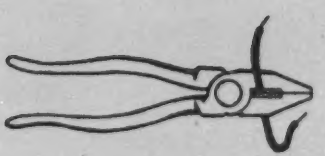
_____y.



_____z.



_____aa.



_____bb.

_____cc.

16. Name four types of micrometers.

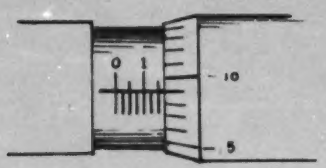
    a.

    b.

    c.

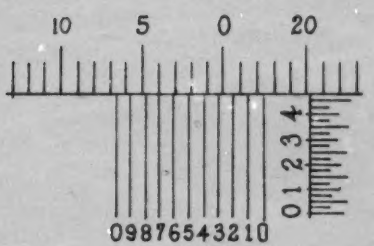
    d.

17. Read the micrometer setting.



Answer_____

18. Read the vernier micrometer setting.



Answer_____

19. Demonstrate the ability to:

    a. Sharpen a twist drill.

    b. Drill holes with a drill press.

    c. Reshape a cold chisel.

    d. Cut flat metal with a cold chisel.

    e. Dress a grinding wheel.

    f. Fit a screwdriver.

g. Replace a hammer handle.

h. Tin a soldering iron.

i. Solder a lap joint.

j. Check a torque wrench for accuracy.

k. Draw file a flat surface.

l. Draw a twist drill to correct center.

m. Use the outside micrometer.

n. Use the vernier micrometer.

o. Cut external threads.

p. Cut internal threads.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

BASIC SHOP TOOLS
UNIT III

ANSWERS TO TEST

1.
a. Common screwdriver
b. Flat file
c. Magnetic pick-up tool
d. Combination box and open-end wrench
e. Slip joint pliers
f. Flat cold chisel
g. Twist drill
h. Center punch
i. Ball peen hammer
j. Screw extractor
k. "C" clamp
l. Hacksaw
m. Tubing cutter
n. Feeler gauge
o. Soldering iron
p. Outside micrometer
q. Vise
r. Pressure gauge (oil pressure)
s. Tachometer
t. Dial indicator
u. External puller
v. Spring tester

2. a. Common
   b. Phillips head
   c. Clutch head
   d. Starting
   e. Offset
3. a. Ball peen
   b. Soft
4. a. Diagonal cutters
   b. Side cutters
   c. Slip joint
   d. Needle nose
   e. Lock grip
   f. Snap ring
5. a. Open end
   b. Adjustable
   c. Box
   d. Tubing
   e. Hook spanner
   f. Adjustable hook spanner
   g. Sliding "T" handle
   h. Extension
   i. Socket
   j. Ratchet handle
   k. Speed handle
   l. Universal joint
   m. Torque
   n. Pipe

o. Monkey

p. Allen

q. Striking

6. a. Flat

b. Cape

c. Round nose

d. Diamond point

7. a. Starting

b. Pin

c. Center

d. Aligning

8. a. Single cut

b. Double cut

c. Rasp cut

d. Curved tooth

9. Any three of the following:

a. Teeth must point away from handle

b. Blade must be tightly stretched

c. Select blade with correct number of teeth per inch for material being cut

d. Use sufficient pressure on the forward stroke

e. Use full length of blade on each stroke

10. a. Shank

b. Flute

c. Cutting edge

11. a. Screw extractor

b. Stud puller

c. Diamond point chisel

12. a. External
    b. Press
    c. Internal
13. a. Revolution counter
    b. Tachometer
    c. Timing light (Stroboscope)
14. a. Standard
    b. Stepped
15. a, c, e, f, h, i, l, m, o, r, u, w, z, aa, bb
16. a. Outside
    b. Inside
    c. Depth
    d. Vernier
17. 0.159
18. 0.4697
19. Performance skills evaluated to the satisfaction of the instructor

TEST EQUIPMENT AND SERVICE TOOLS
UNIT IV

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify testing and servicing tools and match the name of the tools to the correct functions. This knowledge will be evidenced by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with test equipment and service tools to the correct definitions.
2. Name two general types of engine tools and their purposes.
3. Identify types of testing tools.
4. Identify types of servicing tools.
5. Match the testing tools to the correct functions.
6. Match the servicing tools to the correct functions.

TEST EQUIPMENT AND SERVICE TOOLS
UNIT IV

SUGGESTED ACTIVITIES

I. Instructor:

- A. Provide student with objective sheet.
- B. Provide student with information sheet.
- C. Make transparencies.
- D. Discuss unit and specific objectives.
- E. Discuss information sheet.
- F. Demonstrate the use of a valve guide knurling tool.
- G. Give test.

II. Student:

- A. Read objective sheet.
- B. Study information sheet.
- C. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
  1. TM 1--Testing Tools
  2. TM 2--Testing Tools (Continued)
  3. TM 3--Testing Tools (Continued)
  4. TM 4--Testing Tools (Continued)
  5. TM 5--Servicing Tools

6. TM 6--Servicing Tools (Continued)

7. TM 7--Servicing Tools (Continued)

8. TM 8--Servicing Tools (Continued)

9. TM 9--Servicing Tools (Continued)

D. Test

E. Answers to test

II. Reference--*Fundamantals of Service: Engines.* Moline, Illinois: Deere and Company, 1972.

TEST EQUIPMENT AND SERVICE TOOLS
UNIT IV

INFORMATION SHEET

I. Terms and definitions

A. Dynamometer--Applies a load to engine to measure horsepower and fuel consumption

B. Manometer--Tester using mercury or water to test engine vacuums or pressures

C. Knurl--To upset metal thereby decreasing the bore or increasing the outside diameter of a cylindrical object

D. Ream--To enlarge or dressout a hole or bore

E. Diagnose--To recognize by signs or symptoms

F. Thermocouple--Two dissimilar wires joined at one end, and used to measure temperature differences

II. Types of engine tools and their purposes

A. Testing tools--To diagnose the engine

B. Servicing tools--To repair the engine

III. Testing tools (Transparencies 1,2,3, and 4)

A. Cylinder compression tester

B. Cylinder bore gauge

C. Ring groove wear gauge

D. Piston pin bore gauge

E. Plastigage

F. Valve spring tester

G. Injection nozzle tester

H. Injection pump tester

I. Dynamometer

J. Manometer

INFORMATION SHEET

K. Battery hydrometer

L. Thermostat tester

M. Radiator and cap tester

N. Pyrometer

IV. Servicing tools (Transparencies 5, 6, 7, 8, and 9)

A. Valve refacer

B. Valve seat grinder

C. Valve spring compressor

D. Valve guide reamer

E. Valve guide knurling tool

F. Cylinder liner puller-installer

G. Cylinder ridge reamer

H. Cylinder reboring bar

I. Cylinder deglazer

J. Piston ring groove cutting tool

K. Piston ring expander

L. Piston ring compressor

M. Piston and rod aligning tool

N. Injection nozzle removal tools

O. Injection nozzle cleaning kit

P. Valve seat cutter

Q. Valve seat installer

V. Testing tools and their functions

A. Cylinder compression tester--Measures cylinder pressure

B. Cylinder bore gauge--Checks the roundness or taper of a cylinder

C. Ring groove wear gauge--Measures the amount of wear in the piston ring grooves

INFORMATION SHEET

D. Piston pin bore gauge--Measures piston pin bore for precision fits

E. Plastigage--Determines engine bearing clearance

F. Valve spring tester--Checks the strength of valve springs

G. Injector nozzle tester--Checks the condition of needle valve and seat, spray pattern, cracking pressure of nozzle, leak off through nozzle, and nozzle valve lift

H. Injection pump tester--Tests and calibrates diesel fuel injection pump

(NOTE: An injection pump tester tests leakage, vacuum, pressure, and delivery used to make idle and torque control adjustments.)

I. Dynamometer--Applies a load to engine to measure engine horsepower and fuel consumption

J. Manometer--Checks the air intake system of an engine for restrictions

K. Battery hydrometer--Checks the specific gravity of a battery

L. Thermostat tester--Checks the temperature at which the thermostat starts to open

M. Radiator and cap tester--Checks the radiator and cap for leaks and correct opening pressure

N. Pyrometer--Instrument for measuring temperatures beyond the range of a mercurial thermometer

VI. Servicing tools and their functions

A. Valve refacer--Grinds an exact angle on the face of a valve

B. Valve seat grinder--Used to reseat valves with both rough and finishing grinding stones

C. Valve spring compressor--Compresses the spring when removing or installing the valve

D. Valve guide reamer--Reams used valve guides

(NOTE: A valve guide reamer is ideal for cleaning carbon from used guides.)

E. Valve guide knurling tool--Used to resize a worn valve guide

INFORMATION SHEET

F. Cylinder liner puller-installer--Hydraulic or manual tool used to remove or install cylinder liners

G. Cylinder ridge reamer--Removes the ring ridges found at the top of a cylinder or liner

H. Cylinder reboring bar--Used to machine the cylinders of large engines which have integral cylinders

(NOTE: The boring operation is necessary if oversized pistons are to be used.)

I. Cylinder deglazer--Used to deglaze and finish the cylinder or cylinder liner bore

(NOTE: Stone, pad, and brush types of cylinder deglazers are available.)

J. Piston ring groove cutting tool--Used to machine worn piston ring grooves

(NOTE: New standard width rings can be used with flat steel spacers after groove cutting.)

K. Piston ring expander--Used to remove or install piston rings without damage

L. Piston ring compressor--Used to compress the piston rings when installing pistons into the cylinder

M. Piston and rod aligning tool--Checks the piston and rod alignment

(NOTE: Bending bars and clamps are used to correct any bend, twist, or offset in the rod.)

N. Injection nozzle removal tools--Removal and installation kit for some injection nozzles

(NOTE: A typical kit includes hose clamp pliers, nozzle puller, bore cleaning tool, and a guide.)

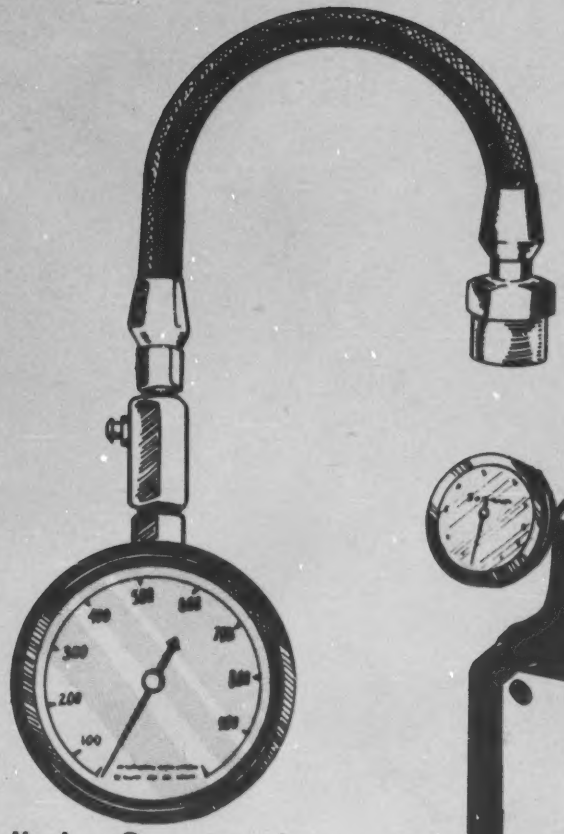
O. Injection nozzle cleaning kit--Kit of tools designed to service one particular make of nozzle

(NOTE: Kits usually include cleaning wires, brushes, drills, and lapping compounds.)

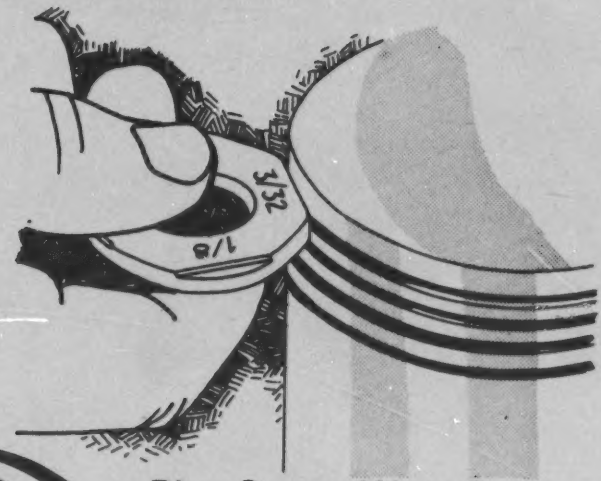
P. Valve seat cutter--Tool used to cut new angles, or dress up valve seat

Q. Valve seat installer--Tool used to install valve seat inserts in the cylinder head

Testing Tools



Cylinder Compression Tester

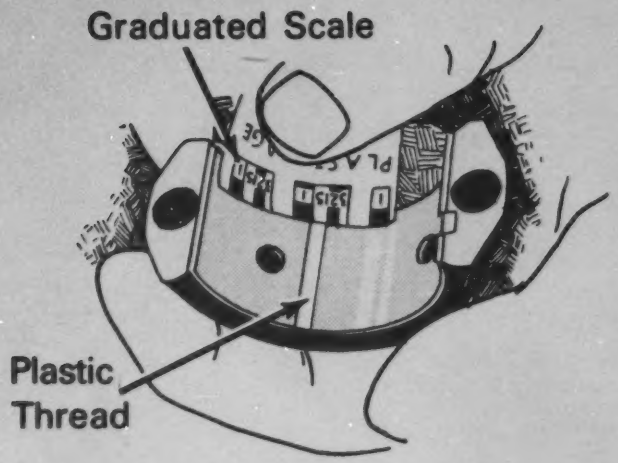


Ring Groove Wear Gauge

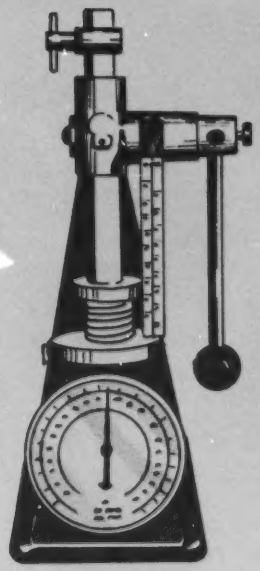
Piston Pin Bore Gauge

Cylinder Bore Gauge

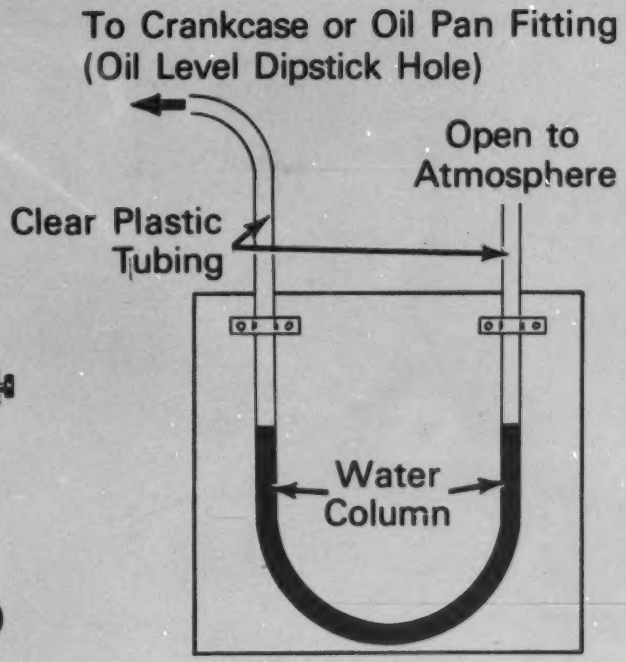
Testing Tools
(Continued)



Plastigage

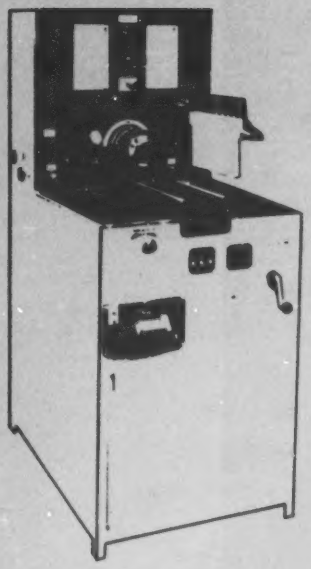


Valve Spring Tester



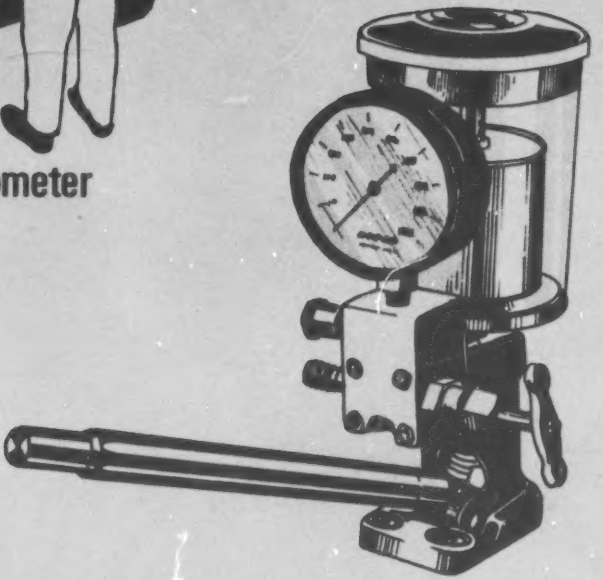
Manometer

Testing Tools
(Continued)



Injection Pump Tester

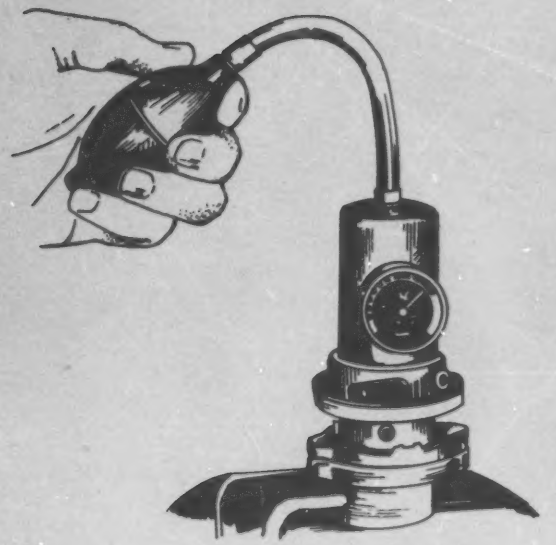
Dynamometer



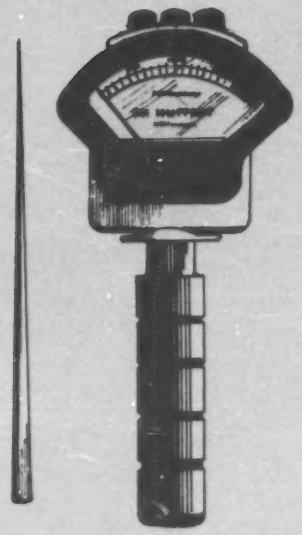
Injection Nozzle Tester (Diesel)

Testing Tools

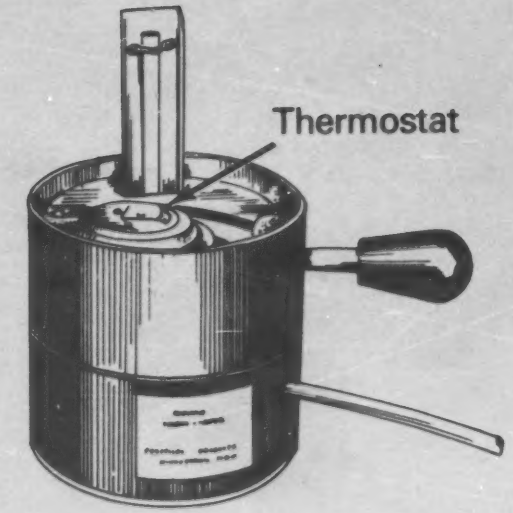
(Continued)



Radiator and Cap Tester



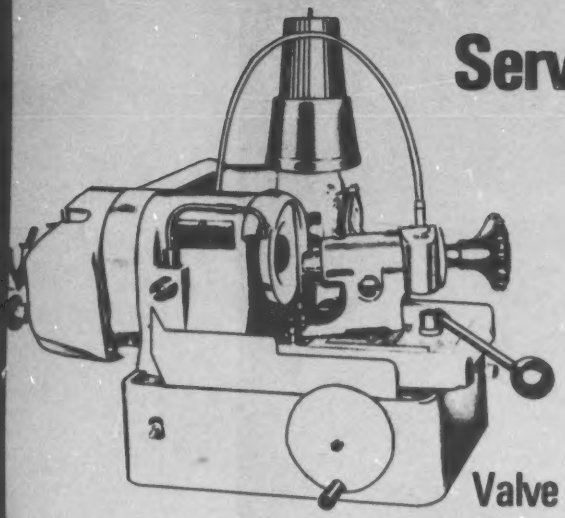
Pyrometer



Thermostat Tester

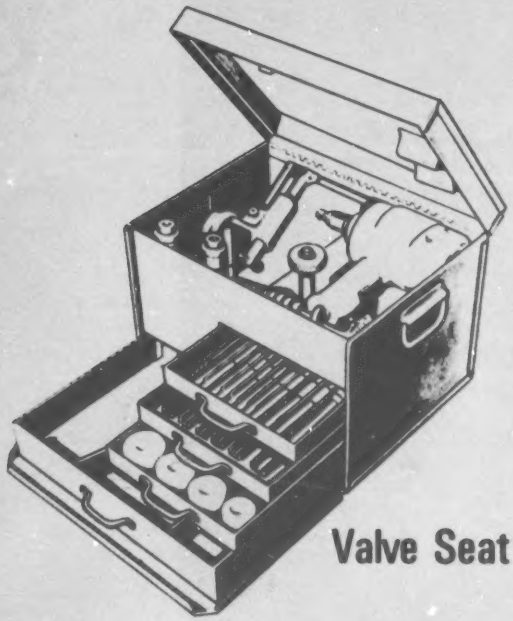
Battery Hydrometer

Servicing Tools

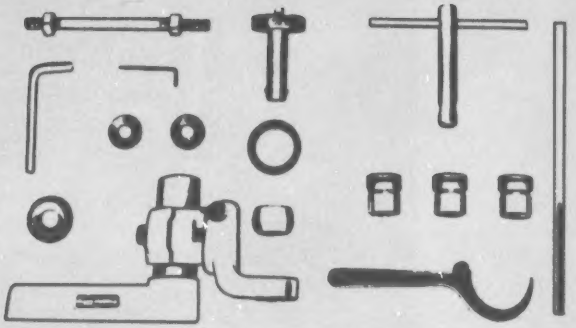


Valve Refacer

Valve Spring Compressor

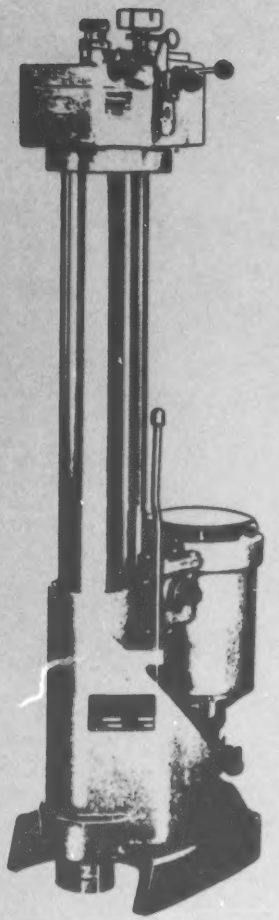


Valve Seat Grinder

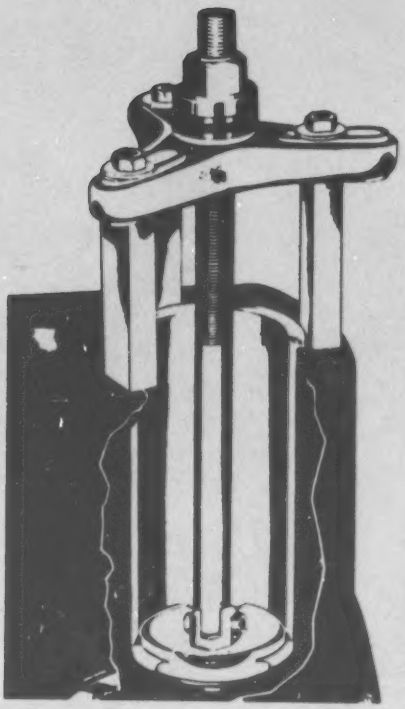


Valve Guide Reamer

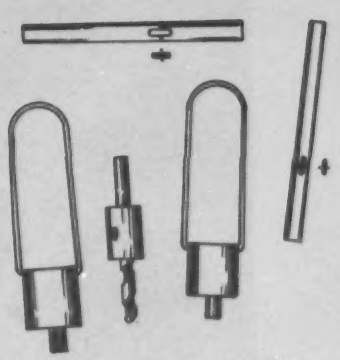
Servicing Tools
(Continued)



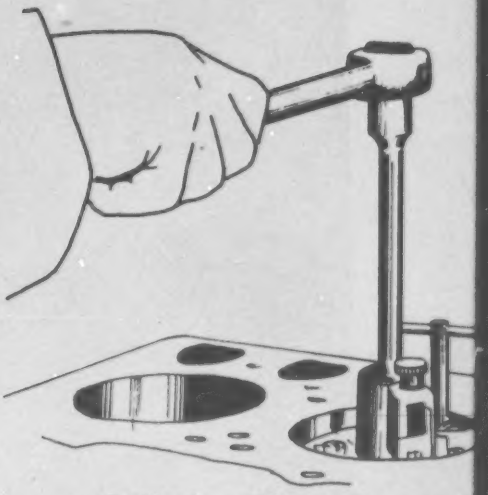
Cylinder Reboring Bar



Cylinder Liner Puller-Installer



Valve Guide Knurling Tool

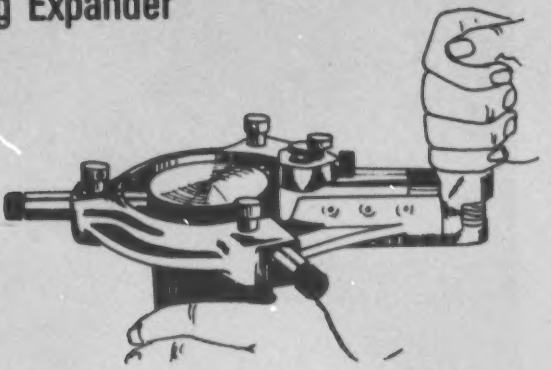


Cylinder Ridge Reamer

Servicing Tools
(Continued)

Cylinder Deglazer

Piston Ring Expander

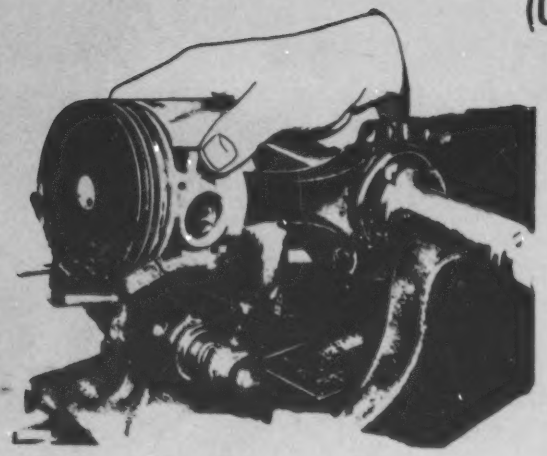


Piston Ring Groove Cutting Tool

Piston Ring Compressor

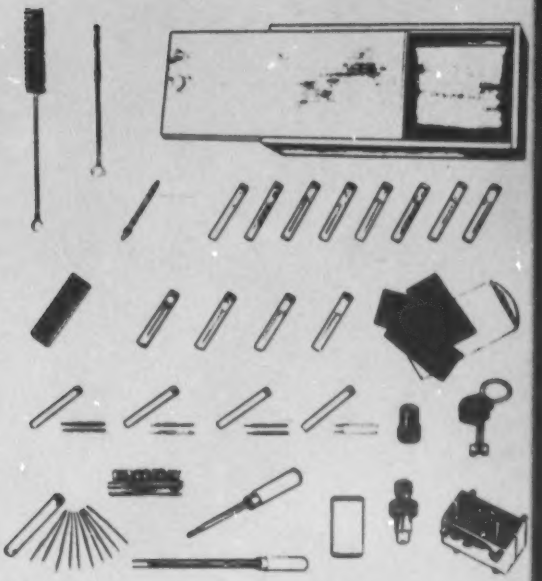
Servicing Tools

(Continued)



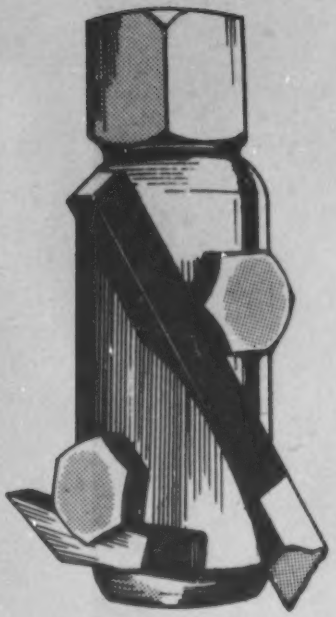
Piston and Rod Aligning Tool

Injection Nozzle Removal Tools (Diesel)

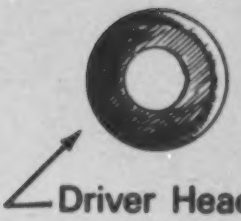


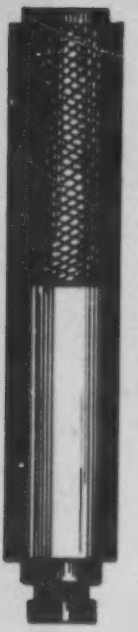
Injection Nozzle Cleaning Kit (Dies

Servicing Tools
(Continued)



Valve Seat Cutter





Valve Seat Installer

TEST EQUIPMENT AND SERVICE TOOLS
UNIT IV

NAME _____

TEST

1. Match terms on the right to the correct definitions.

_____a.	Applies a load to engine to measure horsepower and fuel consumption	1.	Manometer
_____b.	Tester using mercury or water to test engine vacuums or pressures	2.	Dynamometer
_____c.	To upset metal thereby decreasing the bore or increasing the diameter of a cylindrical object	3.	Diagnose
_____d.	To enlarge or dressout a hole or bore	4.	Knurl
_____e.	To recognize by signs or symptoms	5.	Ream
_____f.	Two dissimilar wires joined at one end, and used to measure temperature differences	6.	Thermocouple

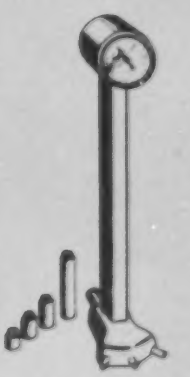
2. Name two general types of engine tools and their purposes.

a.

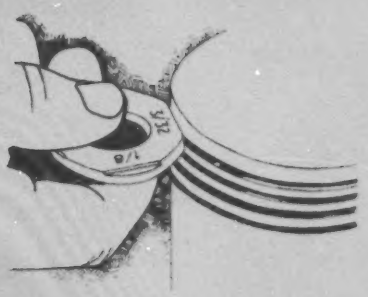
b.

3. Identify the types of testing tools.

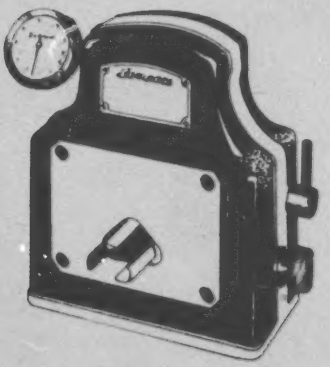
a._____



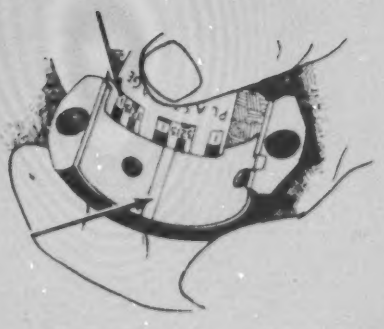
b._____



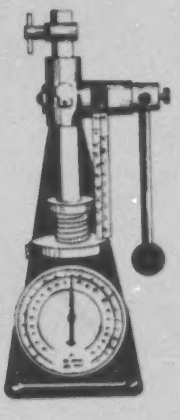
c._____



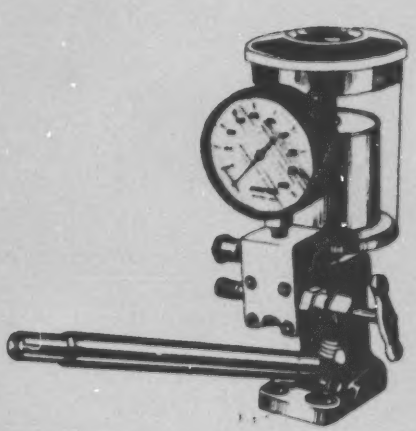
d._____



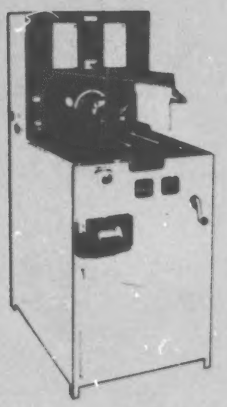
e._____



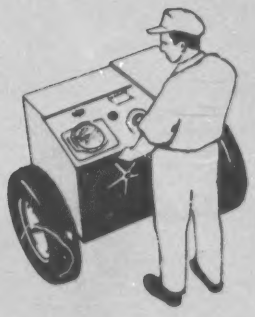
f._____



g._____

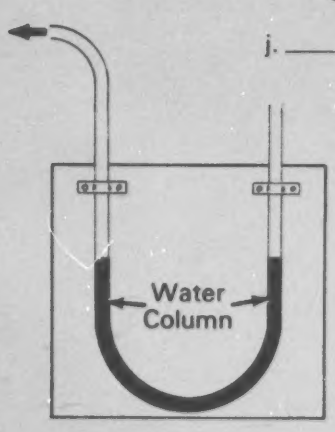


h. _____



i. _____

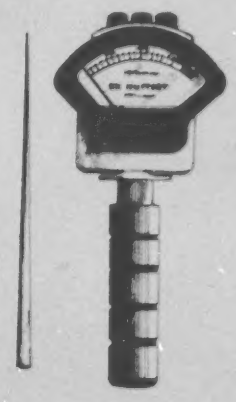
j. _____



k. _____

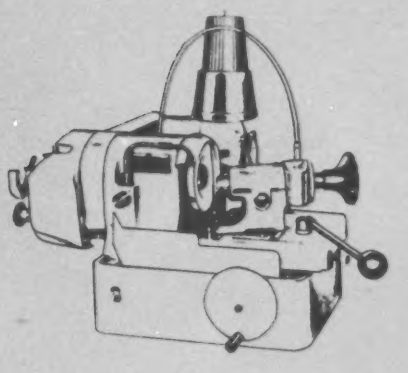
l. _____

m. _____

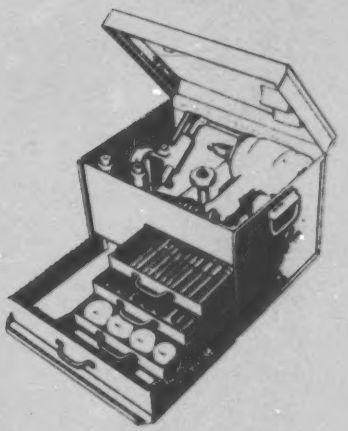


n. _____

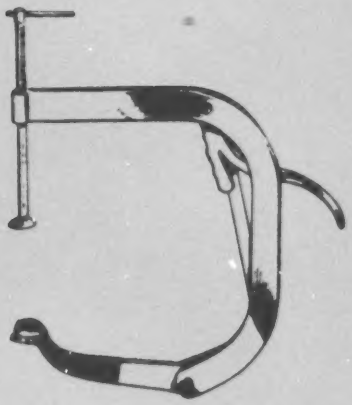
4. Identify the types of servicing tools.



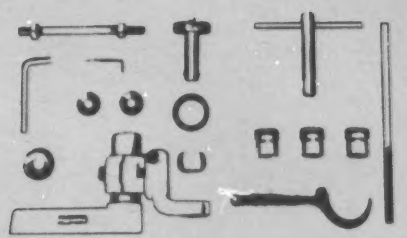
a._____



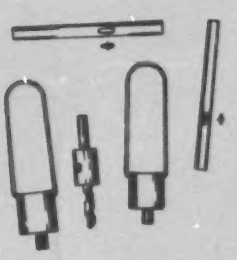
b._____



c._____

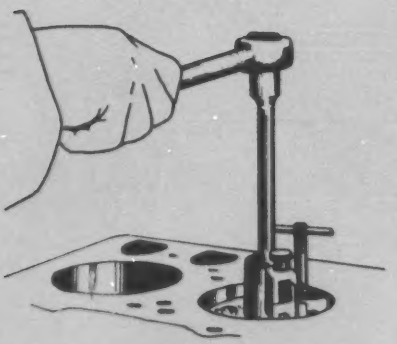


d._____

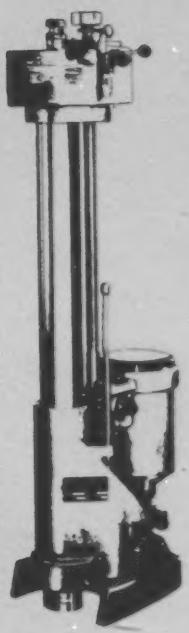


e._____

f._____

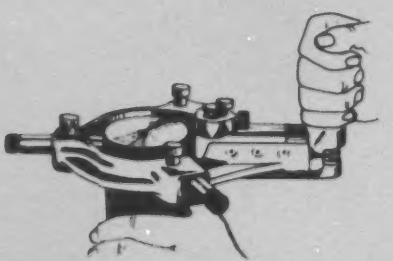


g._____



h._____

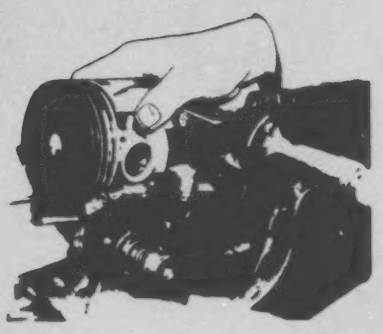
i._____



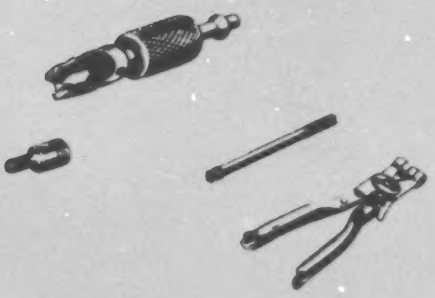
j._____

k. _____

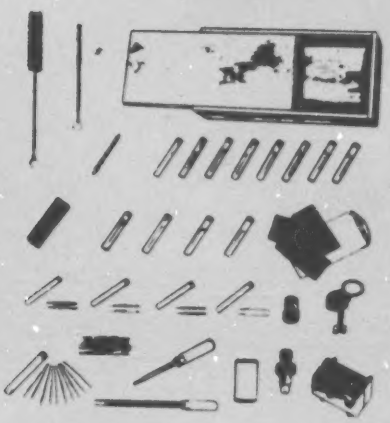
l. _____



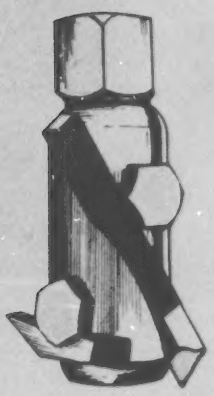
m. _____



n. _____



o. _____



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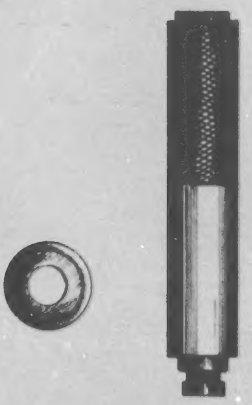


q. _____

5. Match the testing tools on the right to the correct functions.

_____	a. Measures cylinder pressure	1.	Plastigage
_____	b. Checks the roundness or taper of a cylinder	2.	Ring groove wear gauge
_____	c. Measures the amount of wear in the piston ring grooves	3.	Cylinder compression tester
_____	d. Measures piston pin bore for precision fits	4.	Valve spring tester
_____	e. Determines engine bearing clearance	5.	Cylinder bore gauge
_____	f. Checks the strength of valve springs	6.	Injection nozzle tester
_____	g. Checks the condition of needle valve and seat, spray pattern, cracking pressure of nozzle, leak off through nozzle, and nozzle valve lift	7.	Piston pin bore gauge
_____	h. Tests and calibrates diesel fuel injection pump	8.	Radiator and cap tester
_____	i. Applies a load to engine to measure engine horsepower and fuel consumption	9.	Battery hydrometer
_____	j. Checks the air intake system of an engine for restrictions	10.	Thermostat tester
_____	k. Checks the specific gravity of a battery	11.	Dynamometer
_____	l. Checks the temperature at which the thermostat starts to open	12.	Injection pump tester
_____	m. Checks the radiator and cap for leaks and correct opening pressure	13.	Manometer
_____	n. Instrument for measuring temperatures beyond the range of a mercurial thermometer	14.	Pyrometer

6. Match the servicing tools on the right to the correct functions.

_____a. Grinds an exact angle on the face of a valve

_____b. Used to reseat valves with both rough and finishing grinding stones

_____c. Compresses the spring when removing or installing the valve

_____d. Reams used valve guides

_____e. Used to resize a worn valve guide

_____f. Hydraulic or manual tool used to remove or install cylinder liners

_____g. Removes the ring ridges found at the top of a cylinder or liner

_____h. Used to machine the cylinders of large engines which have integral cylinders

_____i. Used to deglaze and finish the cylinder or cylinder liner bore

_____j. Used to machine worn piston ring grooves

_____k. Used to remove or install piston rings without damage

_____l. Used to compress the piston rings when installing pistons into the cylinder

_____m. Checks the piston and rod alignment

_____n. Removal and installation kit for some injection nozzles

_____o. Kit of tools designed to service one particular make of nozzle

_____p. Tool used to cut new angles, or dress up valve seat

_____q. Tool used to install valve seat inserts in the cylinder head

1. Valve spring compressor
2. Injection nozzle cleaning kit
3. Valve seat grinder
4. Piston ring compressor
5. Valve refacer
6. Piston and rod aligning tool
7. Injection nozzle removal tools
8. Piston ring expander
9. Piston ring groove cutting tool
10. Cylinder reboring bar
11. Cylinder deglazer
12. Valve guide knurling tool
13. Cylinder liner puller-installer
14. Valve guide reamer
15. Cylinder ridge reamer
16. Valve seat installer
17. Valve seat cutter

TEST EQUIPMENT AND SERVICE TOOLS
UNIT I

ANSWERS TO TEST

1. a. 2 d. 5
   b. 1 e. 3
   c. 4 f. 6
2. a. Testing tools--To diagnose the engine
   b. Servicing tools--To repair the engine
3. a. Cylinder compression tester
   b. Cylinder bore gauge
   c. Ring groove wear gauge
   d. Piston pin bore gauge
   e. Plastigage
   f. Valve spring tester
   g. Injection nozzle tester
   h. Injection pump tester
   i. Dynamometer
   j. Battery hydrometer
   k. Manometer
   l. Thermostat tester
   m. Radiator and cap tester
   n. Pyrometer
4. a. Valve refacer
   b. Valve seat grinder
   c. Valve spring compressor
   d. Valve guide reamer

e. Valve guide knurling tool
f. Cylinder liner puller-installer
g. Cylinder ridge reamer
h. Cylinder reboring bar
i. Cylinder deglazer
j. Piston ring groove cutting tool
k. Piston ring expander
l. Piston ring compressor
m. Piston and rod aligning tool
n. Injection nozzle removal tools
o. Injection nozzle cleaning kit
p. Valve seat cutter
q. Valve seat installer

5. a. 3 f. 4 j. 13 n. 14
b. 5 g. 6 k. 9
c. 2 h. 12 l. 10
d. 7 i. 11 m. 8
e. 1

6. a. 5 f. 13 k. 8 p. 17
b. 3 g. 15 l. 4 q. 16
c. 1 h. 10 m. 6
d. 14 i. 11 n. 7
e. 12 j. 9 o. 2

FASTENERS
UNIT V

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify typical fasteners, discuss how bolts and threads are measured, and select qualities of satisfactory fasteners. The student should also be able to select methods used to remove seized nuts and select tools used to restore threads. This knowledge will be evidenced by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with fasteners to the correct definitions.
2. Select qualities of satisfactory fasteners.
3. Identify typical fasteners.
4. Identify typical bolt head styles.
5. Discuss how bolt sizes, lengths, and threads are measured.
6. Match the grade of bolts to the markings on the head of bolt.
7. Identify typical nuts.
8. Identify special purpose nuts with locking or self-locking features.
9. Select methods used to remove a seized nut.
10. Identify five types of washers.
11. Select tools used to restore bolt threads.
12. Select tools used to restore internal threads.
13. List four devices for locking nuts or bolts.
14. Identify types of machine screw head designs.
15. Identify four types of snap rings.

FASTENERS
UNIT IV

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information sheet.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1-Typical Fasteners
2. TM 2--Bolt Head Styles
3. TM 3--How to Measure Bolts and Threads
4. TM 4--SAE Grade Markings for Steel Bolts and Screws
5. TM 5--Typical Nuts
6. TM 6--Special Purpose Nuts

7. TM 7--Methods Used to Remove a Seized Nut
8. TM 8--Types of Washers
9. TM 9--Tools Used to Restore Bolt Threads and Internal Threads
10. TM 10--Devices for Locking Nuts or Bolts
11. TM 11--Machine Screw Head Designs
12. TM 12--Types of Snap Rings

D. Test

E. Answers to test

II. Reference--*Fundamentals of Service: Fasteners.* Moline, Illinois: Deere and Company, 1974.

FASTENERS
UNIT V

INFORMATION SHEET

I. Terms and definitions

A. Bolt--Metal rod or pin for fastening objects together that has a head at one end, a screw thread at the other end, and is secured by a nut

B. Screw--Pointed and headed cylindrical fastener that is threaded and designed for insertion into material by rotating

C. Fastener--Device used to secure or hold together separate items

D. Tap--Tool for forming an internal screw thread

E. Die--Internally threaded screw cutting tool used for forming external screw threads

F. Stud--Steel rod with threads on both ends, to be screwed permanently into a fixed part at one end and receive a nut on the exposed end

G. SAE--Society of Automotive Engineers

II. Qualities of satisfactory fasteners

A. Strong

B. Reusable

C. Easy to remove

D. Withstand vibration

E. Long lasting

F. Corrosion resistant

G. Temperature resistant

III. Typical fasteners (Transparency 1)

A. Hex head bolt

B. Wing nut

C. Stud

INFORMATION SHEET

D. Woodruff key

E. Cap screw

F. Socket head bolt

G. Tapping screw

H. Tooth lock washer

I. Rivet

J. Bolt and nut

K. Cotter pin

L. Square key

M. Flat washer

N. Plow bolt

O. Carriage bolt

P. Castle nut

Q. Lock washer

R. Adhesive

S. Lock pin

T. Snap ring

U. Machine screw

V. Set screw

W. Spring lock pin

X. Locking nut

Y. Clevis pin

IV. Typical bolt head styles (Transparency 2)

A. Hex head bolt

B. Hex socket head bolt

INFORMATION SHEET

C. Plow bolt

D. Square head cap screw

E. 12-point head bolt

F. Askew head bolt

G. Carriage bolt

H. Hex flange screw

V. Measuring bolts and threads (Transparency 3)

A. Size of bolt is determined by measuring the diameter of the thread end

B. Length of bolt is determined by measuring the distance from bottom of the head to the end of the threads

(NOTE: Some carriage bolts with round, flat, tapered heads are measured from the top of the head to the end of the threads.)

C. Number of threads per inch is determined by measuring with a rule or a thread gauge

(NOTE: American National Standards established the unified screw thread standard. Course threads are U.S. standard and fine threads are S.A.E. threads.)

VI. Grade markings for steel bolts (Transparency 4)

A. SAE-Grade 1 and 2--No marking on head of bolt

B. SAE-Grade 5--Three marks (slashes) on head of bolt

C. SAE-Grade 7--Five marks (slashes) on head of bolt

D. SAE-Grade 8--Six marks (slashes) on head of bolt

VII. Typical nuts (Transparency 5)

A. Acorn

B. Castle

C. Spring

INFORMATION SHEET

D. Wing

E. Hex

F. Flanged

G. Lock

H. Slotted

I. Weld

J. Panel

K. Serrated

L. Single thread

M. Specialty

VIII. Special purpose nuts with locking or self-locking features (Transparency 6)

A. Prevailing torque lock nut

B. Plastic insert lock nut

C. Jam nut

D. Castle nut

E. Slotted nut

F. Wing nut

G. Speed nut

H. Anchor nut

I. Chamfered nut

J. Cap nut

K. Flange-lock nut

L. Pal nut

INFORMATION SHEET

IX. Methods used to remove a seized nut (Transparency 7)

A. Penetrating oil

B. Hacksaw

C. Nut splitter

D. Chisel

E. Gas torch

X. Types of washers (Transparency 8)

A. Flat washer

B. Lock washer

C. External toothed lock washer

D. Internal toothed lock washer

E. Countersunk external toothed washer

XI. Tools used to restore bolt threads (Transparency 9)

A. Rethreading tool

B. Thread restorer

C. Rethreading die

XII. Tools to restore internal threads (Transparency 9)

A. Internal thread chaser

B. Hand tap

XIII. Devices for locking nuts or bolts (Transparency 10)

A. Cotter pins

B. Lock wire

C. Flat metal locks

D. Lock ears

INFORMATION SHEET

XIV. Types of machine screw head designs (Transparency 11)

A. Round

B. Fillister

C. Truss

D. Pan

E. Oval

F. Cross recessed or phillips

G. Flat

H. Clutch

I. Hex slotted

XV. Types of snap rings (Transparency 12)

A. Internal prong

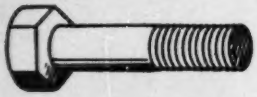
B. Internal hole

C. External hole

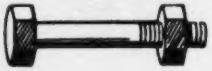
D. External "E"

Typical Fasteners

Hex Head Bolt

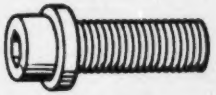


Bolt and Nut



Plow Bolt

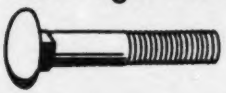
Socket Head Bolt



Stud

Cap Screw

Carriage Bolt



Tapping Screw

Machine Screw

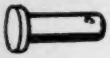
Set Screw

Woodruff Key

Square Key

Rivet

Clevis Pin



Flat Washer

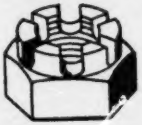
Lock Washer

Toothed Lock Washer

Locking Nut

Wing Nut

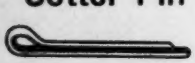
Castle Nut



Snap Ring

Spring Lock Pin

Cotter Pin

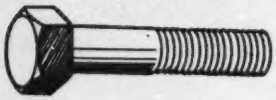


Lock Pin

Adhesive

Bolt Head Styles

Hex Head Bolt

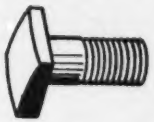


Hex Socket Head Bolt

Plow Bolt

Square Head
Cap Screw

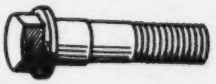
Askew Head Bolt



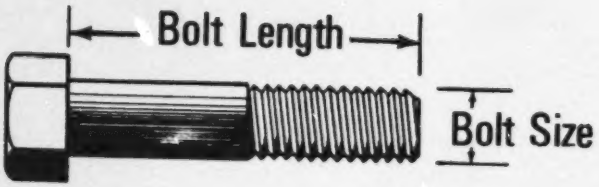
12-Point Head Bolt

Carriage Bolt

Hex Flange Screw

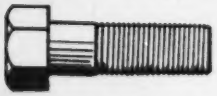


How to Measure Bolts and Threads

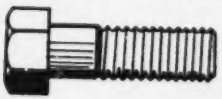


Measuring Threads Per Inch

Fine Thread



Coarse Thread



Thread Gauge

SAE GRADE MARKINGS FOR STEEL BOLTS AND SCREWS

Grade Marking	Specification	Material	Tensile Strength min., psi.
	SAE-Grade 0	Steel	
	SAE-Grade 1	Low Carbon Steel	55,000
	SAE-Grade 2	Low Carbon Steel	69,000
	SAE-Grade 5	Medium Carbon Steel, Quenched and Tempered	120,000
	SAE-Grade 7	Medium Carbon Steel, Quenched and Tempered	133,000
	SAE-Grade 8	Med. Carbon Alloy Steel, Quenched and Tempered	150,000

Typical Nuts

Acorn

Castle

Spring

Wing

Hex

Flanged

Lock

Slotted

Weld

Panel

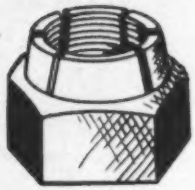
Specialty

Serrated

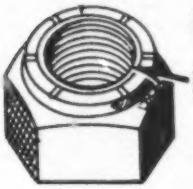
Single Thread

Special Purpose Nuts

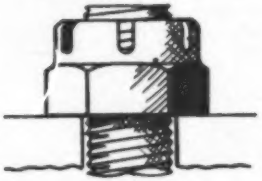
Prevailing Torque Lock Nut



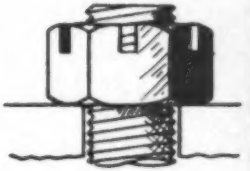
Plastic Insert Lock Nut



Castle Nut



Slotted Nut



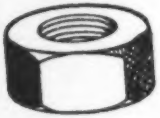
Jam Nut

Wing Nut

Speed Nut

Anchor Nut

Chamfered Nut (Both Sides)

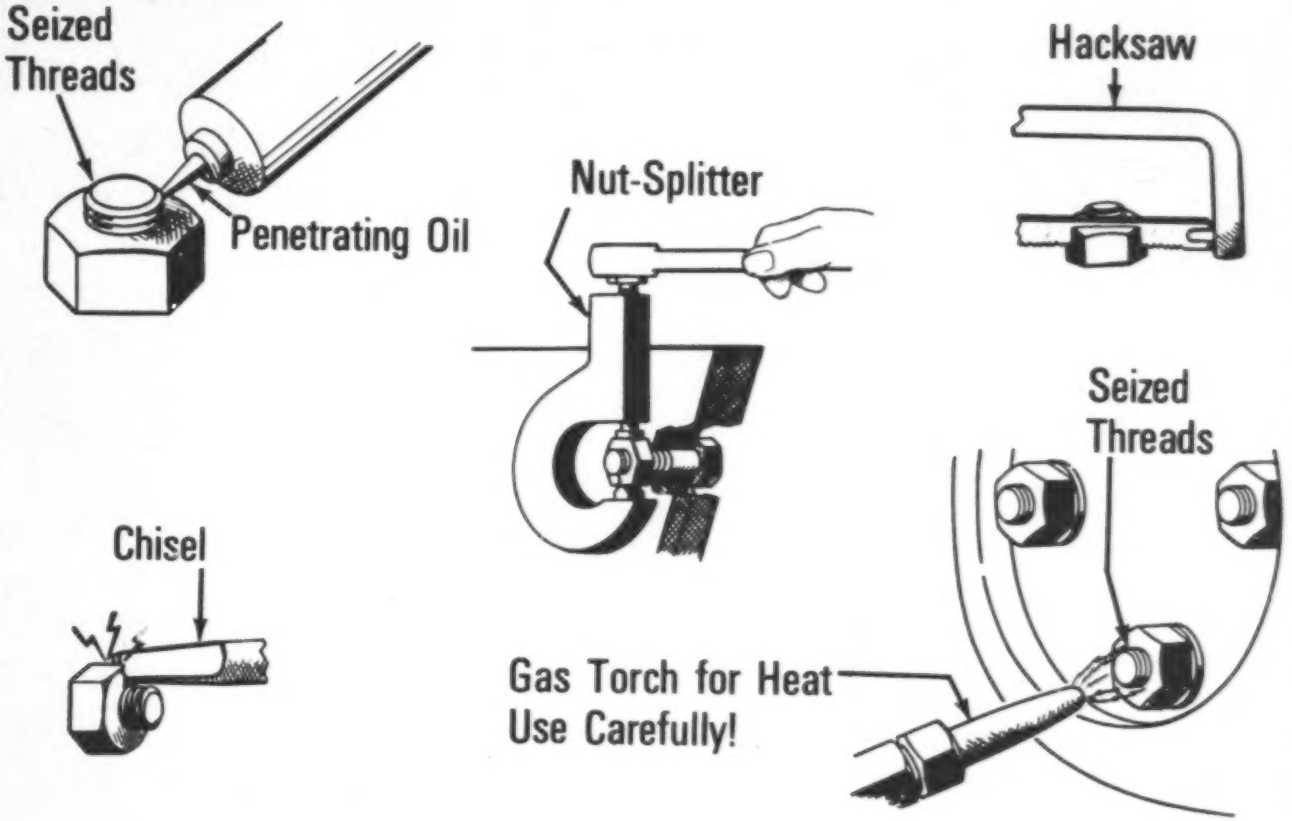


Cap Nut

Flange-Lock Nut

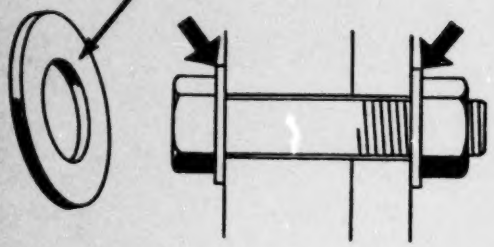
Pal Nut

Methods Used to Remove a Seized Nut



Types of Washers

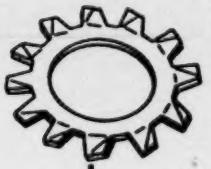
Flat Washer



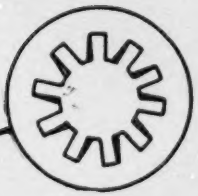
Lock Washer

(Washer Grips)

External Toothed
Lock Washer



Internal Toothed
Lock Washer



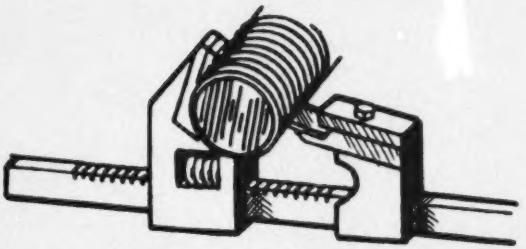
Countersunk
External Toothed Washer

Tools Used to Restore Bolt Threads and Internal Threads

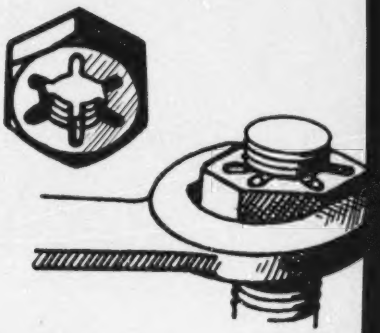
Bolt Threads

Thread Restorer (Tile-Like)

Rethreading Tool



Rethreading Die

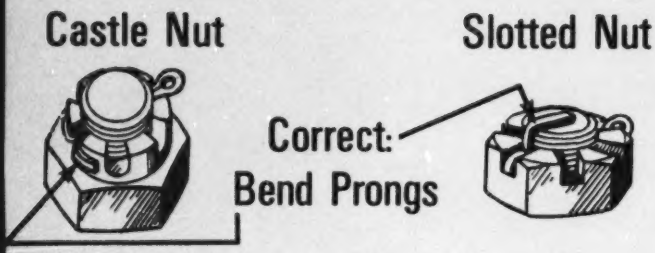


Internal Theads

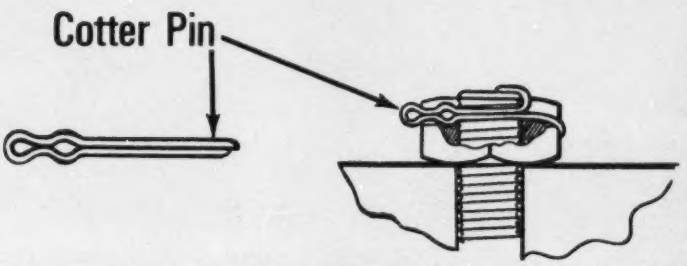
Internal Thread Chasers

Hand Tap

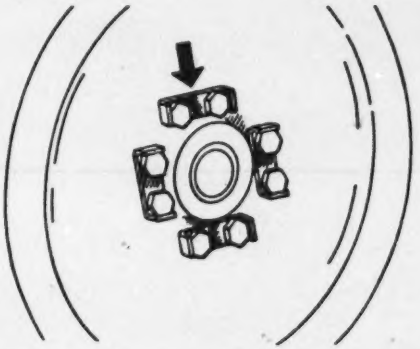
Devices for Locking Nuts or Bolts



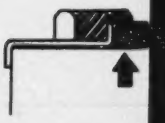
Cotter Pin Prongs Properly Bent Around Castle Nut and a Slotted Nut



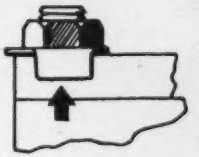
Double-Head Cotter Pin in Use



Flat Metal Locks Hold Flywheel Bolts in Place



Lock Ears Properly Bent Into Place



Machine Screw Head Designs

Round

Fillister

Cross Recessed or Phillips

Flat

Oval

Truss

Pan

Clutch

Hex Slotted

Types of Snap Rings

Internal Prong

Internal Hole

External Hole

External "E"

Snap Ring

FASTENERS
UNIT V

NAME _____

TEST

1. Match the terms on the right to the correct definitions.

_____a. Metal rod or pin for fastening objects together that has a head at one end, a screw thread at the other end, and is secured by a nut

_____b. Pointed and headed cylindrical fastener that is threaded and designed for insertion into material by rotating

_____c. Device used to secure or hold together separate items

_____d. Internally threaded screw cutting tool used for forming external screw threads

_____e. Tool for forming an internal screw thread

_____f. Steel rod with threads on both ends, to be screwed permanently into a fixed part at one end and receive a nut on the exposed end

_____g. Society of automotive engineers

1. Tap
2. Stud
3. Screw
4. Die
5. Fastener
6. Bolt
7. SAE

2. Select qualities of satisfactory fasteners by placing an "X" in the appropriate blanks.

_____a. Easy to remove

_____b. Must be used with two washers

_____c. Strong

_____d. Temperature resistant

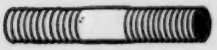
_____e. Be threaded on both ends

_____f. Reusable

3. Identify the typical fasteners.

a. _____

b. _____



c. _____

d. _____

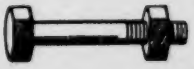
e. _____

f. _____

g. _____

h. _____

i. _____



j. _____

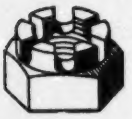
k. _____

l. _____

m. _____

n. _____

o. _____



p. _____

q. _____

r. _____

s. _____

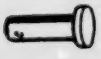
t. _____

u. _____

v. _____

w. _____

x. _____



y. _____

4. Identify the typical bolt head styles.

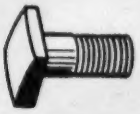
a. _____

b. _____

c. _____

d. _____

e. _____



f. _____

g. _____

h. _____

5. Discuss how bolt sizes, lengths, and threads are measured.

6. Match the grade of bolts on the right to the markings on the head of the bolt.

_____a.

_____b.

_____c.

_____d.

1. SAE-Grade 7
2. SAE-Grade 5
3. SAE-Grade 1 and 2
4. SAE-Grade 8

7. Identify the typical nuts.

a. _____

b. _____

c. _____

d. _____

e. _____

f. _____

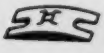
g. _____

h. _____

i. _____

j. _____

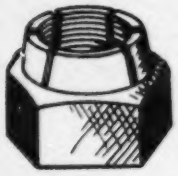
k. _____



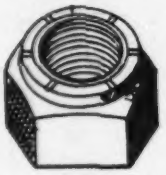
l. _____

m. _____

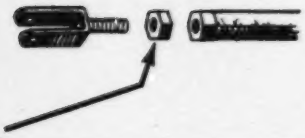
8. Identify the special purpose nuts with locking or self-locking features.



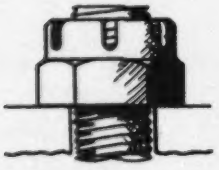
a. _____



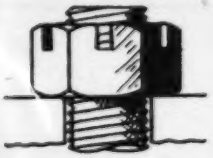
b. _____



c. _____



d. _____



e. _____

f. _____

g. _____

h. _____

i. _____

j. _____

k. _____

l. _____

9. Select methods used to remove a seized nut by placing an "X" in the appropriate blanks.

_____a. Hacksaw

_____b. Chisel

_____c. Gas torch

_____d. Hot water

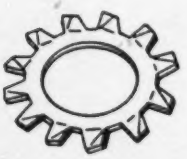
_____e. Screwdriver

_____f. Penetrating oil

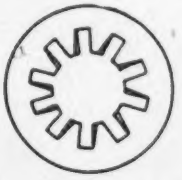
10. Identify five types of washers.

a. _____

b. _____



c. _____



d. _____

e. _____

11. Select tools used to restore bolt threads by placing an "X" in the appropriate blanks.

_____a. Rethreading tap

_____b. Rethreading die

_____c. Rethreading tool

_____d. Die stock

12. Select a tool used to restore internal threads by placing an "X" in the appropriate blank.

_____a. Threading die

_____b. Chisel

_____c. Hand tap

13. List four devices for locking nuts or bolts.

a.

b.

c.

d.

14. Identify the types of machine screw head designs.

a. _____

b. _____

c. _____

d. _____

e. _____

f. _____

g. _____

h. _____

i. _____

15. Identify four types of snap rings.

a. _____

b. _____

c. _____

d. _____

FASTENERS
UNIT V

ANSWERS TO TEST

1. a. 6
   b. 3
   c. 5
   d. 4
   e. 1
   f. 2
   g. 7
2. a, c, d, f
3. a. Hex head bolt
   b. Wing nut
   c. Stud
   d. Woodruff key
   e. Cap screw
   f. Socket head bolt
   g. Tapping screw
   h. Tooth lock washer
   i. Rivet
   j. Bolt and nut
   k. Cotter pin
   l. Square key
   m. Flat washer
   n. Plow bolt
   o. Carriage bolt
   p. Castle nut
   q. Lock washer
   r. Adhesive

s. Lock pin

t. Snap ring

u. Machine screw

v. Set screw

w. Spring lock pin

x. Locking nut

y. Clevis pin

4. a. Hex head bolt

b. Hex socket head bolt

c. Plow bolt

d. Square head cap screw

e. 12-point head bolt

f. Askew head bolt

g. Carriage bolt

h. Hex flange screw

5. Discussion should include:

a. Size of bolt is determined by measuring the diameter of the thread end

b. Length of bolt is determined by measuring the distance from bottom of the head to the end of the threads

c. Number of threads per inch is determined by measuring with a rule or a thread gauge

6. a. 3

b. 2

c. 1

d. 4

7. a. Castle

b. Spring

c. Wing

d. Hex

e. Flanged

f. Lock

g. Acorn

h. Slotted

i. Weld

j. Panel

k. Serrated

l. Single thread

m. Specialty

8. a. Prevailing torque lock nut

b. Plastic insert lock nut

c. Jam nut

d. Castle nut

e. Slotted nut

f. Wing nut

g. Speed nut

h. Anchor nut

i. Chamfered nut

j. Cap nut

k. Flange-lock nut

l. Pal nut

9. a, b, c, f

10. a. Flat washer

b. Lock washer

c. External toothed lock washer

d. Internal toothed iock washer

e. Countersunk external toothed washer

11. b, c,

12. c

13. a. Cotter pins

b. Lock wire

c. Flat metal locks

d. Lock ears

14. a. Round

b. Fillister

c. Truss

d. Pan

e. Oval

f. Flat

g. Cross recessed or phillips

h. Clutch

i. Hex slotted

15. a. Internal hole

b. External "E"

c. Internal prong

d. External hole

ENGINE OPERATING PRINCIPLES
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify basic parts of a diesel engine and match these parts to their functions. The student should also be able to discuss the operation of the diesel engine, distinguish between the differences in the diesel engine and the gasoline engine, and explain the basic difference between a four stroke cycle and a two stroke cycle engine. This knowledge will be evidenced by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with engine operating principles to the correct definitions.
2. Identify basic parts of a diesel engine.
3. Match basic diesel engine parts to their functions.
4. Discuss the operation of the diesel engine.
5. Explain what happens during each stroke of a four stroke cycle engine.
6. Explain the basic difference between two stroke and four stroke engines.
7. Discuss the characteristics of two-cycle and four-cycle engines.
8. Distinguish between the differences in diesel engines and gasoline engines.

ENGINE OPERATING PRINCIPLES
UNIT I

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information sheet.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Cylinder Terms
2. TM 2--Compression Ratio
3. TM 3--Piston Crown Designs
4. TM 4--Piston Stroke
5. TM 5--Basic Parts of a Diesel Engine
6. TM 6--Internal Engine Parts

7. TM 7--Diesel Engine Combustion

8. TM 8--Four Stroke Cycle Operation

9. TM 9--Two Stroke Cycle Operation

D. Test

E. Answers to test

II. References:

A. Kates, Edgar J., and Luck, William E. *Diesel and High Compression Gas Engines.* Chicago: American Technical Society, 1972.

B. *Fundamentals of Service: Engines.* Moline, Illinois: Deere and Company, 1972.

C. *Detroit Diesel Allison, Service Manual.* Detroit, Michigan: General Motors Corp., 1973.

ENGINE OPERATING PRINCIPLES
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Volume--Total space between the piston at its lowest position in the cylinder and the bottom of the cylinder head (Transparency 1)

B. Clearance volume--Total space between the piston at its highest position in the cylinder and the cylinder head (Transparency 1)

C. Compression--The reduction in volume of gases trapped in the cylinder by the upward motion of the piston.

D. Compression ratio--Ratio of whole cylinder volume to least cylinder volume (Transparency 2)

(NOTE: The least cylinder volume is the clearance volume.)

E. Compression ignition--Ignition of the fuel by the heat from compression

F. Temperature--Measure of heat intensity

G. Combustion--Action or operation of burning

H. Pre-combustion chamber--Cavity in the cylinder head of some diesels where some burning of fuel first takes place

I. Piston crown--Surface shape of the top of the piston (Transparency 3)

J. TDC (Top Dead Center)--Piston at highest point of travel (Transparency 4)

K. BDC (Bottom Dead Center)--Piston at lowest point of travel (Transparency 4)

L. Stroke--Distance the piston moves when traveling from TDC to BDC (Transparency 4)

M. Engine speed--Crankshaft revolutions per minute

N. Power control--Controlling the engine power by varying or governing the amount of fuel injected into the combustion chamber

O. Cycle--Series of events that repeat themselves in a regular sequence

INFORMATION SHEET

II. Basic parts of a diesel engine (Transparencies 5 and 6)

A. Cylinder block

B. Cylinders

C. Pistons

D. Connecting rod

E. Crankshaft

F. Crankshaft gear

G. Camshaft

H. Timing gear

I. Cam lobes

J. Push rods

K. Rocker arms

L. Valve

M. Valve lifter

N. Cylinder head

O. Cooling passageway

P. Wrist pin

Q. Flywheel

R. Oil pump

S. Oil pan

T. Intake valve

U. Exhaust valve

III. Basic diesel engine parts and their functions (Transparencies 5 and 6)

A. Cylinder block--Solid casting which includes the cylinders and water jackets

B. Cylinders--Holes in the cylinder block containing the pistons

INFORMATION SHEET

C. Pistons--Movable plugs open at one end which transfer force of explosion to the connecting rod

D. Connecting rod--Connecting link between the piston and crankshaft

E. Crankshaft--Main shaft of an engine which, turned by the connecting rods, changes the reciprocating motion of the piston to the rotary motion in the power train

(NOTE: Portions are offset to form throws to which the connecting rods are attached.)

F. Crankshaft gear--Drives the camshaft or idler gear

G. Camshaft--Shaft with cam lobes used to operate the valves

H. Timing gear--Gear by which the camshaft is driven by the crankshaft

I. Cam lobes--Eccentrics on the camshaft that operate the valves

J. Push rods--Rod links that transfer motion from the lifter to the rocker arm

K. Rocker arm--Transfers motion from push rod to valve to open the valve

L. Valve lifter--Rides on the camshaft so that the cam lobe raises it to operate the valve

(NOTE: The valve lifter is also called the cam follower.)

M. Valves--Open and close the cylinder to allow air to enter or gases to leave the cylinder

N. Cylinder head--Metal section bolted to the block to close one end of the cylinder, which usually contains the valves

O. Cooling passageway--Hollow space in block through which coolant circulates

P. Wrist pin--Serves as floating connecting piece for piston and connecting rod

Q. Oil pump--Provides pressure that circulates oil to rotating or reciprocating engine parts to minimize friction

R. Oil pan--Reservoir for engine oil

S. Intake valve--Permits air to enter the cylinder

INFORMATION SHEET

T. Exhaust valve--Opens and allows exhaust gases to be forced from engine cylinder

U. Flywheel--Attaches to the end of the crankshaft and provides inertia to carry the crankshaft around from one firing impulse to the other

IV. Operation of the diesel engine (Transparency 7)

A. Piston moves up on compression stroke

1. Air is trapped in the cylinder causing pressure to rise

2. Pressure rise causes high temperature

B. Piston reaches top dead center

1. Fuel is injected into the cylinder

2. Hot compressed air ignites the fuel

3. Combustion occurs

C. Combustion creates energy to force the piston down on the power stroke

(NOTE: Power is controlled by amount of fuel injected into the cylinder.)

V. Strokes in a four stroke cycle engine (Transparency 8)

A. First stroke--Intake

1. Piston moves down

2. Exhaust valve closed

3. Intake valve open

B. Second stroke--Compression

1. Piston moves up

2. Intake and exhaust valve closed

C. Third stroke--Power (ignition)

1. Piston going down

2. Intake and exhaust valve closed

INFORMATION SHEET

D. Fourth stroke--Exhaust

1. Piston moves up
2. Intake valve closed
3. Exhaust valve open

VI. Difference between two stroke and four stroke engines

A. Four stroke cycle--Fires every other time piston reaches top dead center (Transparency 8)

(NOTE: Crankshaft makes two revolutions and piston makes four strokes.)

B. Two stroke cycle--Fires each time piston reaches top dead center (Transparency 9)

(NOTE: Crankshaft makes one revolution and piston makes two strokes but completes all four events in the cycle. Cylinder has been charged by a blower forcing air through ports near bottom of cylinder.)

VII. Characteristics of two-cycle and four-cycle engines

A. Two-cycle

1. Produces a power stroke for each revolution of the crankshaft
2. Theoretically produces twice the power for the same size engine
3. Smoother running as power strokes occur at shorter intervals

B. Four-cycle

1. Heat problem is less due to each cylinder firing half as often
2. Does not use engine power to drive a blower to force air charge into the cylinder under pressure
3. Burned gasses are completely cleared from the cylinder, resulting in more power per power stroke
4. Exhaust valves or ports open later creating some gain in effective power

INFORMATION SHEET

VIII. Diesel and gasoline engine differences

A. Fuel ignition

1. Diesel--Ignition by compression

2. Gasoline--Ignition by electrical spark

B. Intake air

1. Diesel--Takes fresh air directly to combustion chamber

2. Gasoline--Takes fresh air and fuel through carburetor, then to combustion chamber

C. Compression

1. Diesel--High compression ratio (16-22:1)

2. Gasoline--Low compression ratio (7-11:1)

D. Fuel

1. Diesel--Burns low grade fuel oil

2. Gasoline--Burns gasoline

E. Fuel delivery system

1. Diesel--Fuel injected directly into combustion chamber

2. Gasoline--Fuel and air mixture drawn through carburetor and intake manifold into combustion chamber

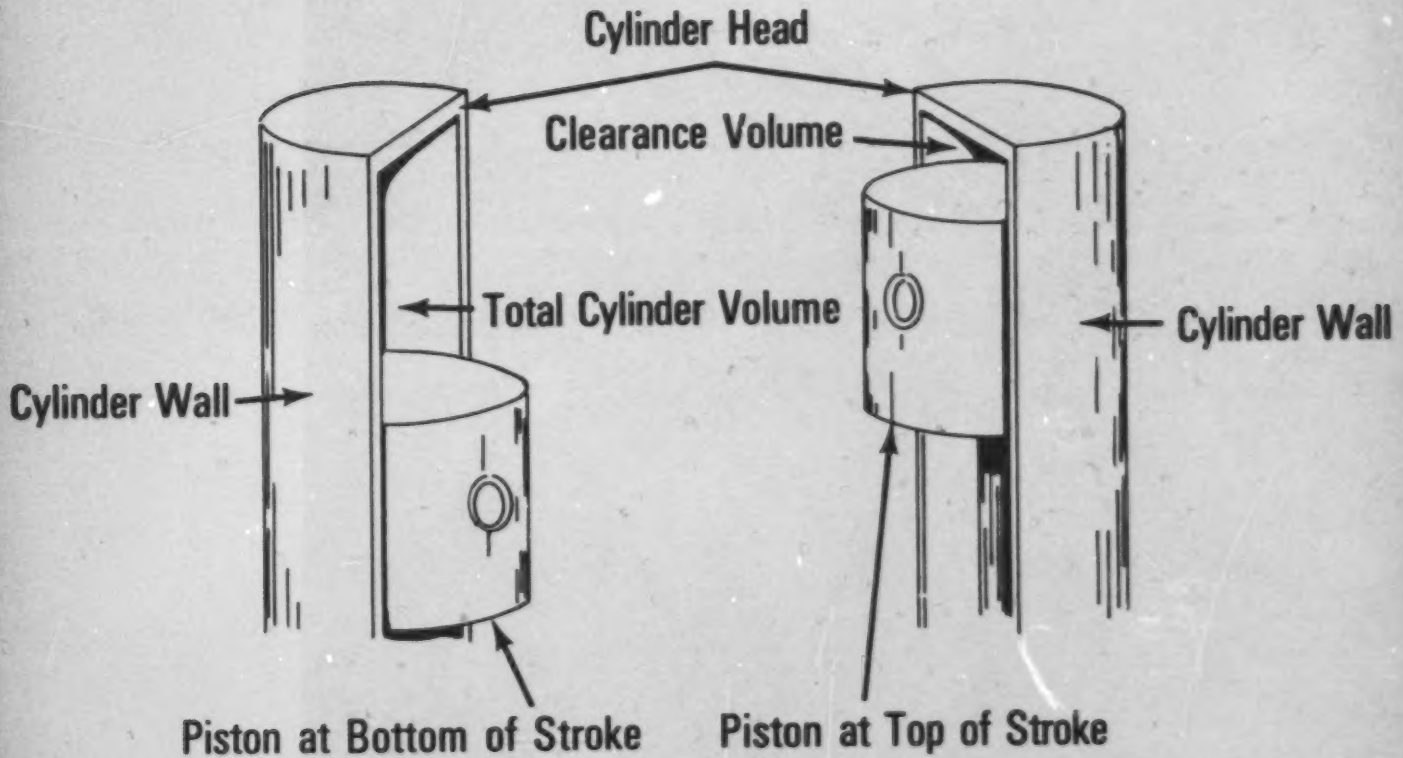
F. Construction

1. Diesel--Heavier construction

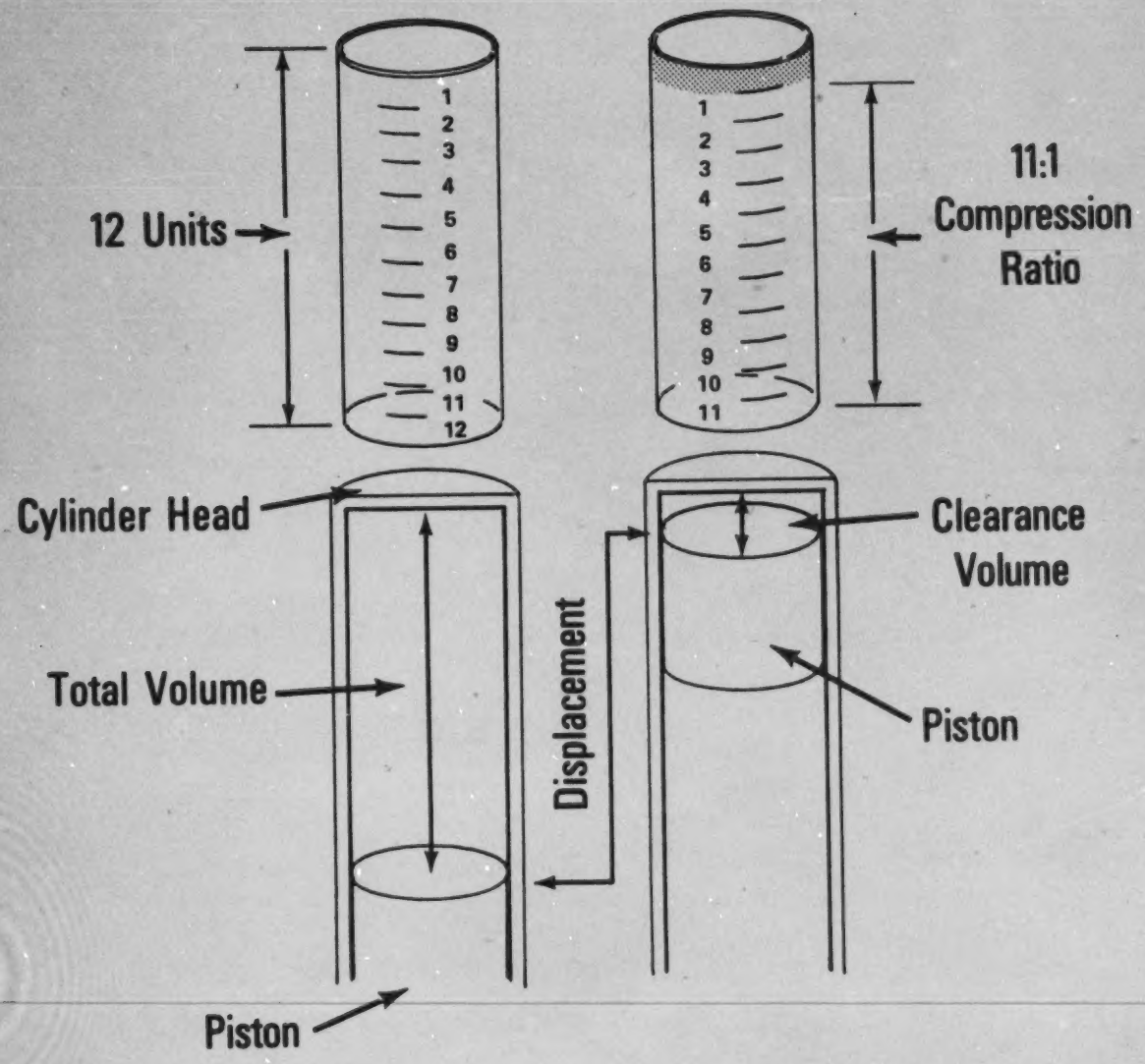
(NOTE: Heavy construction is required to handle the high pressure and temperature generated in a diesel engine.)

2. Gasoline--Lighter construction

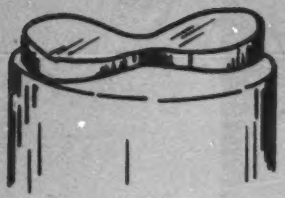
Cylinder Terms

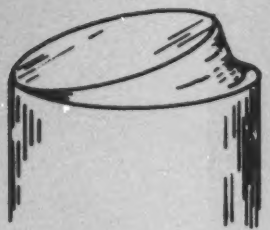


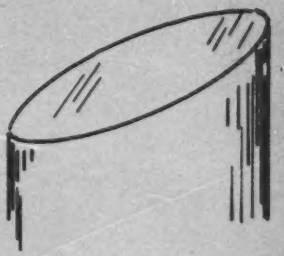
Compression Ratio



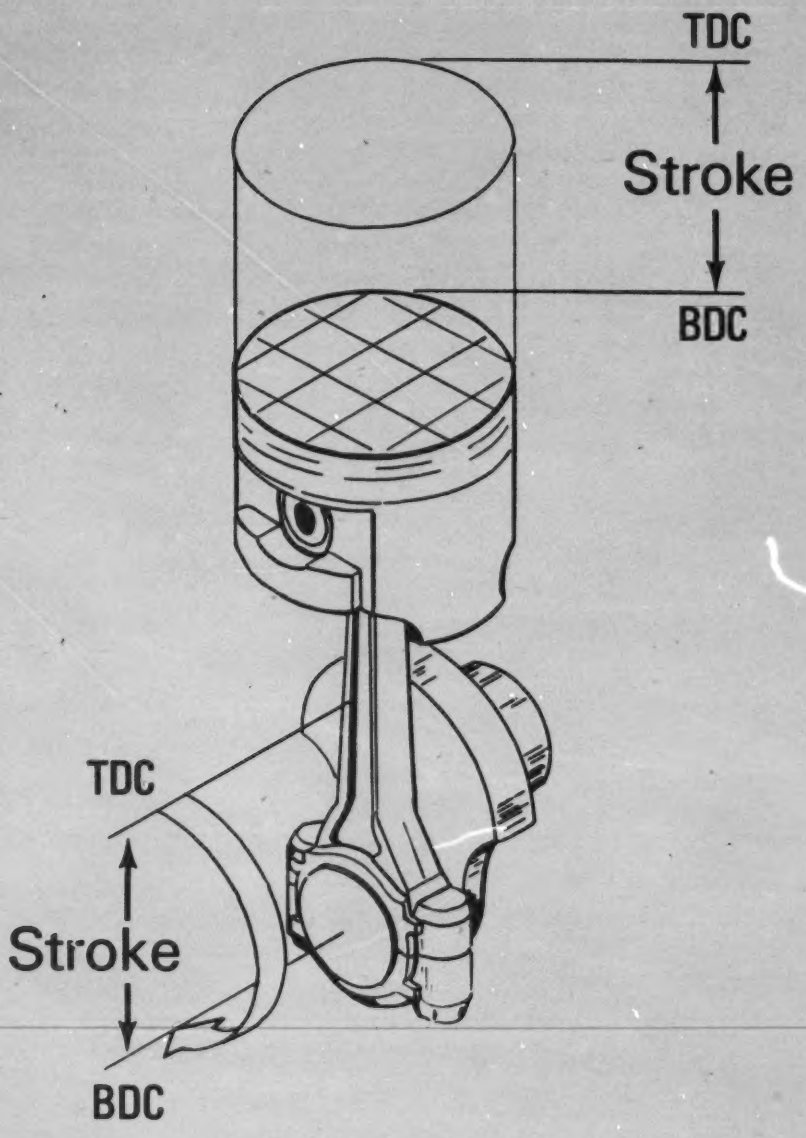
Piston Crown Designs



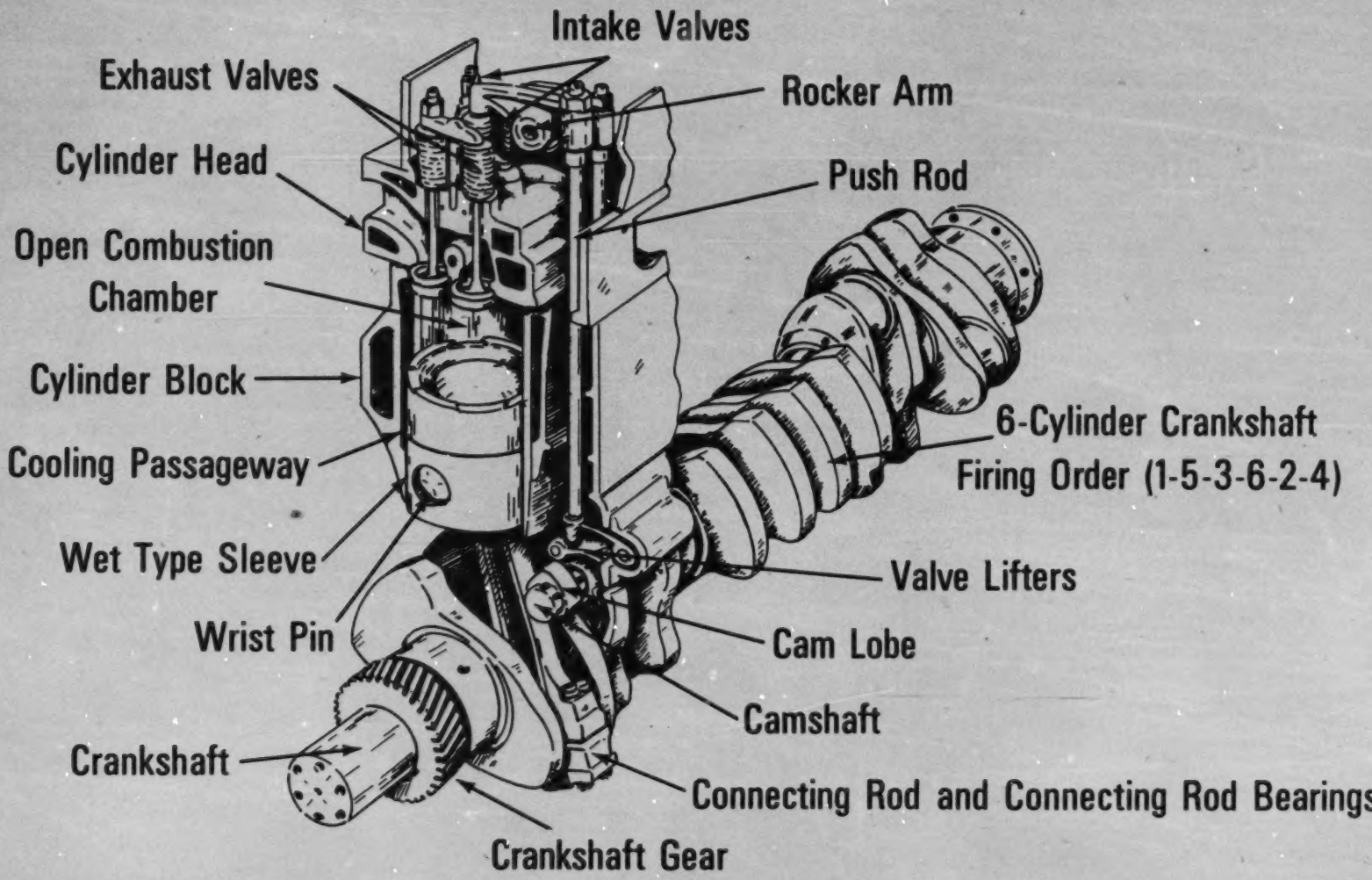




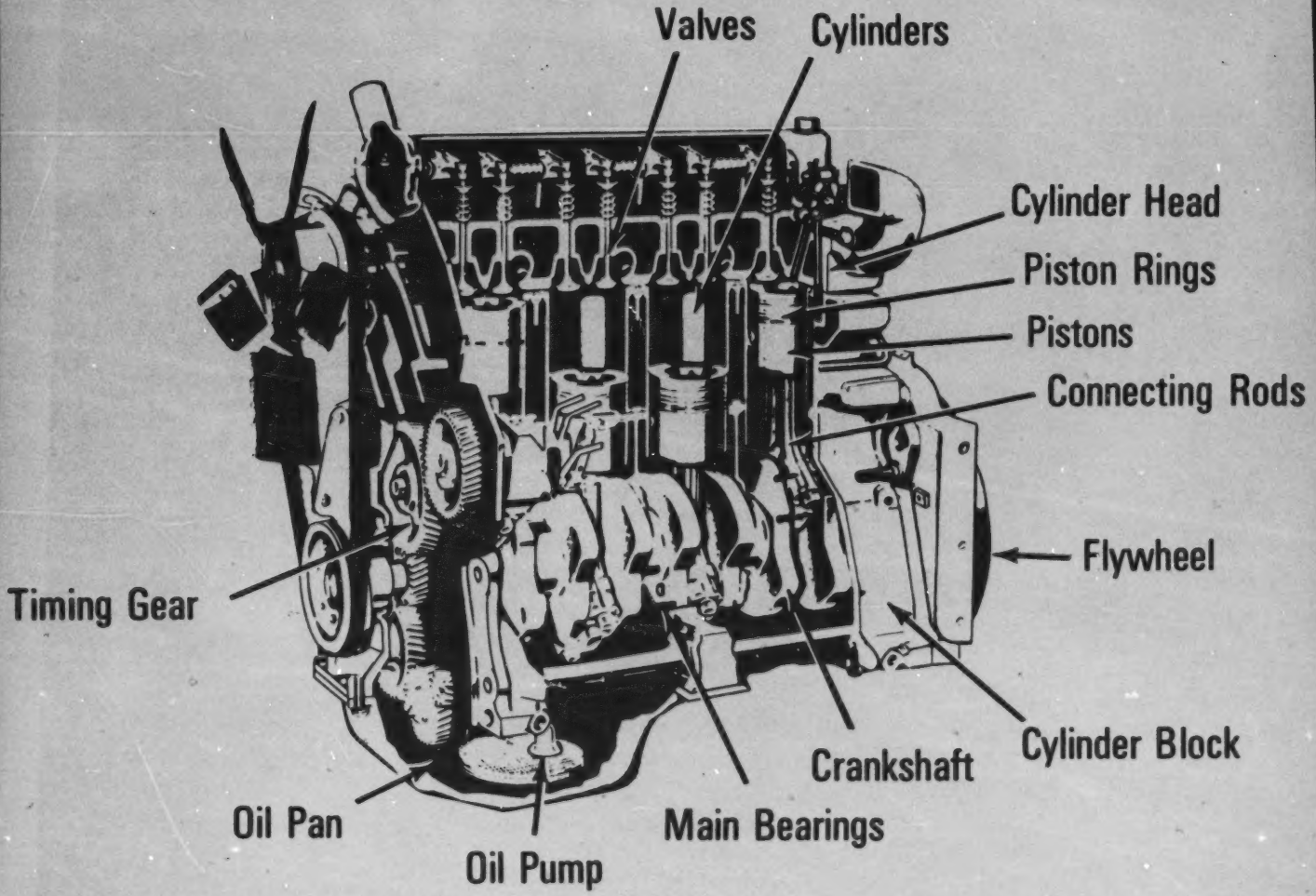
Piston Stroke



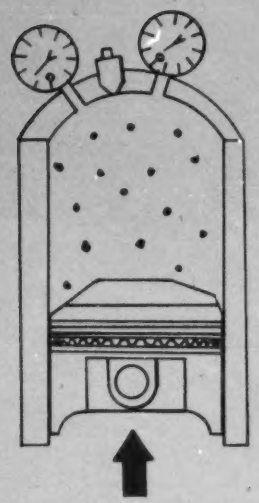
Basic Parts of a Diesel Engine



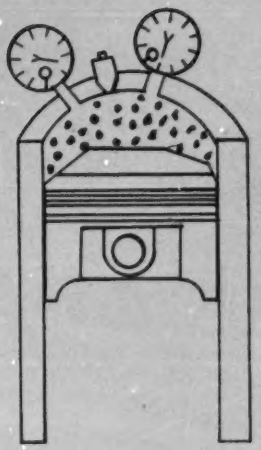
Internal Engine Parts



Diesel Engine Combustion

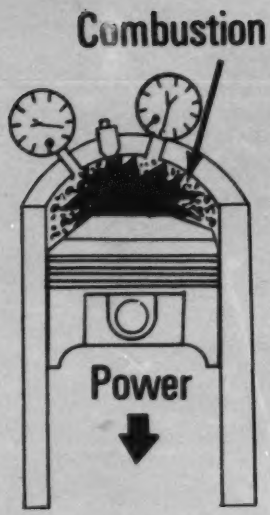


Piston moves up on compression stroke



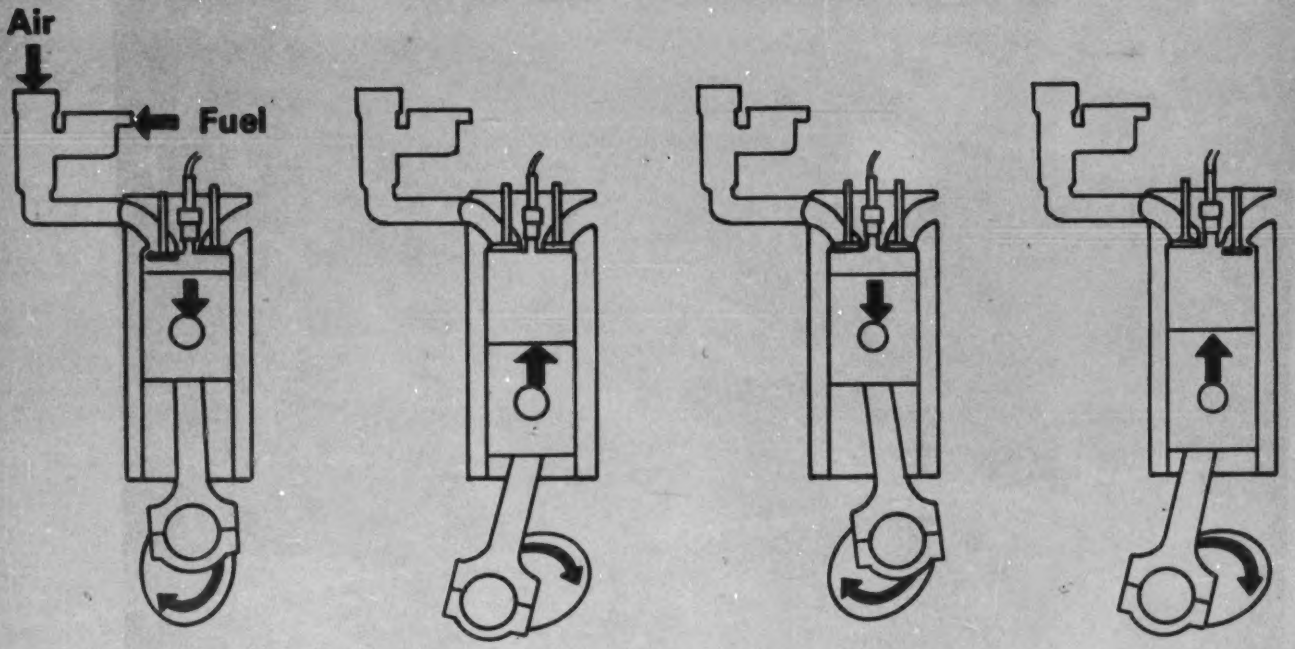
Air is trapped in the cylinder causing pressure to rise

Piston reaches TDC and fuel is injected into the cylinder



Hot compressed air ignites the fuel, combustion occurs, and this creates energy to force the piston down on the power stroke

Four Stroke Cycle Operation



INTAKE

Fuel-air mixture is drawn into cylinder from carburetor through open intake valve by down-stroke of piston.

COMPRESSION

Mixture is compressed by up-stroke of piston. Both intake and exhaust valves are closed.

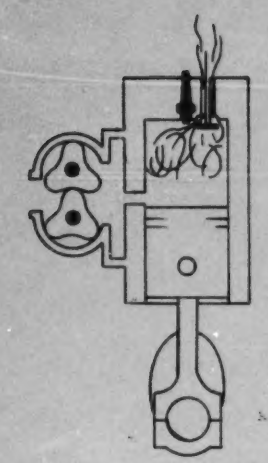
POWER

Compressed mixture is ignited by spark plug and expanding gases force piston to bottom of cylinder. Valves remain closed.

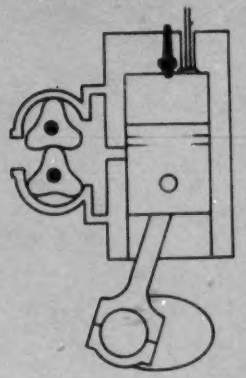
EXHAUST

Piston on up-stroke forces burned gases from cylinder through open exhaust valve.

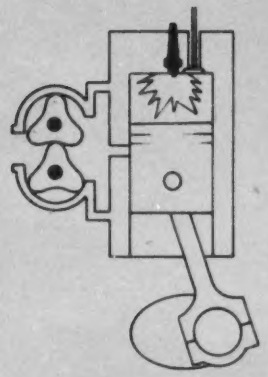
Two Stroke Cycle Operation



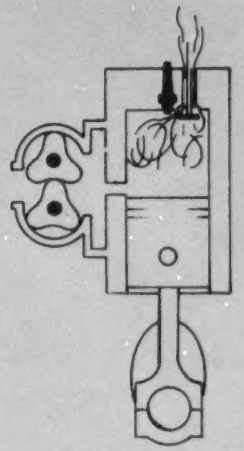
Intake



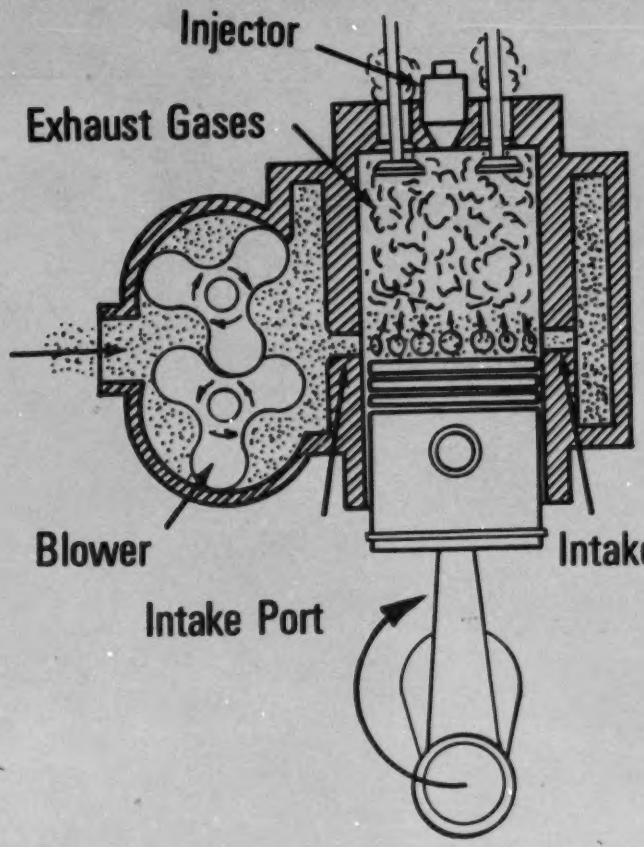
Compression



Power



Exhaust



ENGINE OPERATING PRINCIPLES
UNIT I

NAME_____

TEST

1. Match the terms on the right to the correct definitions.

_____a. Total space between the piston at its lowest position in the cylinder and the bottom of the cylinder head

_____b. Total space between the piston at its highest position in the cylinder and the cylinder head

_____c. The reduction in volume of gases trapped in the cylinder by the upward motion of the piston

_____d. Ratio of whole cylinder volume to least cylinder volume

_____e. Ignition of the fuel by the heat from compression

_____f. Measure of heat intensity

_____g. Action or operation of burning

_____h. Cavity in the cylinder head of some diesels where some burning of fuel first takes place

_____i. Piston at highest point of travel

_____j. Piston at lowest point of travel

_____k. Distance the piston moves when traveling from TDC to BDC

_____l. Crankshaft revolutions per minute

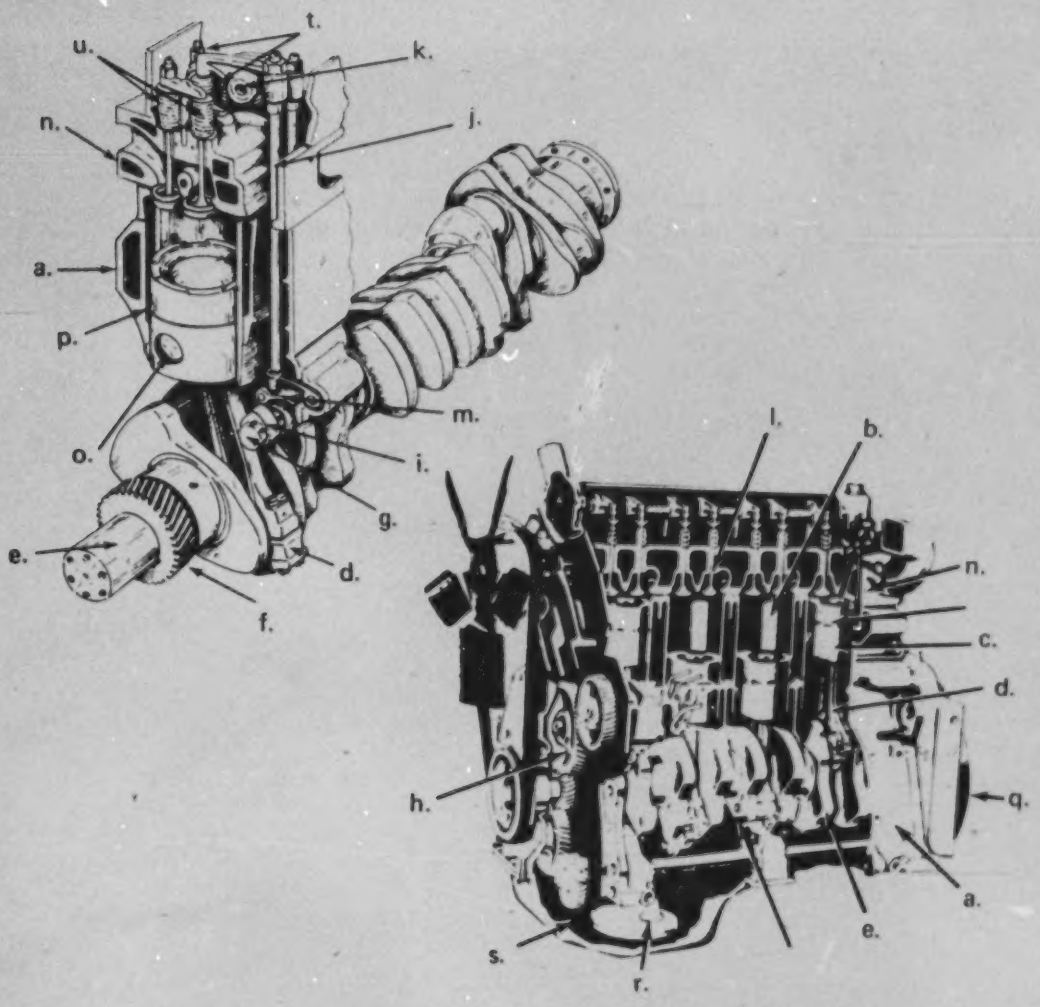
_____m. Controlling the engine power by varying or governing the amount of fuel injected into the combustion chamber

_____n. Surface shape of the top of the piston

_____o. Series of events that repeat themselves in a regular sequence

1. Piston crown
2. Power control
3. Engine speed
4. Stroke
5. BDC (Bottom Dead Center)
6. TDC (Top Dead Center)
7. Combustion
8. Pre-combustion chamber
9. Compression
10. Temperature
11. Compression ignition
12. Compression ratio
13. Volume
14. Cycle
15. Clearance volume

2. Identify fifteen basic parts of a diesel engine.



a. _____ f. _____

b. _____ g. _____

c. _____ h. _____

d. _____ i. _____

e. _____ j. _____

k. _____ q. _____

l. _____ r. _____

m. _____ s. _____

n. _____ t. _____

o. _____ u. _____

p. _____

3. Match the basic parts on the right to their correct functions. (The answers for "a" through "l" are on this page.)

_____a. Solid casting which includes the cylinders and water jackets

_____b. Holes in the cylinder block containing the pistons

_____c. Movable plugs open at one end which transfer force of explosion to the connecting rod

_____d. Connecting link between the piston and crankshaft

_____e. Main shaft of an engine which, turned by the connecting rods, changes the reciprocating motion of the piston to the rotary motion in the power train

_____f. Drives the camshaft or idler gear

_____g. Shaft with cam lobes used to operate the valves

_____h. Gear by which the camshaft is driven by the crankshaft

_____i. Eccentrics on the camshaft that operate the valves

_____j. Rod links that transfer motion from the lifter to the rocker arm

_____k. Transfers motion from push rod to valve to open the valve

_____l. Rides on the camshaft so that the cam lobe raises it to operate the valve

1. Valve lifter
2. Connecting rod
3. Crankshaft
4. Push rods
5. Rocker arm
6. Timing gear
7. Cylinders
8. Cylinder block
9. Cam lobes
10. Pistons
11. Crankshaft gear
12. Camshaft

(The answers for "m" through "u" are on this page.)

_____m. Opens and allows exhaust gases to be forced from engine cylinder

_____n. Metal section bolted to the block to close one end of the cylinder, which usually contains the valves

_____o. Provides pressure that circulates oil to rotating or reciprocating engine parts to minimize friction

_____p. Serves as floating connecting piece for piston and connecting rod

_____q. Hollow space in block through which coolant circulates

_____r. Reservoir for engine oil

_____s. Permits air to enter the cylinder

_____t. Open and close the cylinder to allow air to enter or gases to leave the cylinder

_____u. Attaches to the end of the crankshaft and provides inertia to carry the crankshaft around from one firing impulse to the other

13. Valves
14. Oil pan
15. Flywheel
16. Oil pump
17. Intake valve
18. Cylinder head
19. Exhaust valve
20. Cooling passageway
21. Wrist pin

4. Discuss the operation of the diesel engine.

5. Explain what happens during each stroke of a four stroke cycle engine.

6. Explain the basic difference between two stroke and four stroke engines.

7. Discuss the characteristics of two-cycle and four-cycle engines.

8. Distinguish between the differences in diesel engines and gasoline engines by placing an "X" next to the descriptions of diesel engines.

_____a. Ignition by compression

_____b. Burns gasoline

_____c. Lighter construction

_____d. High compression ratio

_____e. Heavier construction

_____f. Takes fresh air directly to combustion chamber

_____g. Ignition by electrical spark

_____h. Low compression ratio

_____i. Burns low grade fuel oil

_____j. Fuel and air mixture drawn through carburetor and intake manifold into combustion chamber

_____k. Takes fresh air and fuel through carburetor then to combustion chamber

_____l. Fuel injected directly into combustion chamber

ENGINE OPERATING PRINCIPLES
UNIT I

ANSWERS TO TEST

1.

a.	13	g.	10	m.	3
b.	16	h.	7	n.	2
c.	15	i.	8	o.	1
d.	9	j.	6	p.	14
e.	12	k.	5		
f.	11	l.	4		

2. Any fifteen of the following:

a. Cylinder block

b. Cylinders

c. Pistons

d. Connecting rod

e. Crankshaft

f. Crankshaft gear

g. Camshaft

h. Timing gear

i. Cam lobes

j. Push rods

k. Rocker arms

l. Valve

m. Valve lifter

n. Cylinder head

o. Wrist pin

p. Cooling passageway

q. Flywheel

r. Oil pump

s. Oil pan

t. Intake valve

u. Exhaust valve

3.

a.	8	h.	6	o.	16
b.	7	i.	9	p.	21
c.	10	j.	4	q.	20
d.	2	k.	5	r.	14
e.	3	l.	1	s.	17
f.	11	m.	19	t.	13
g.	12	n.	18	u.	15

4. Discussion should include:

a. Piston moves up on compression stroke

1) Air is trapped in the cylinder causing pressure to rise

2) Pressure rise causes high temperature

b. Piston reaches top dead center

1) Fuel is injected into the cylinder

2) Hot compressed air ignites the fuel

3) Combustion occurs

c. Combustion creates energy to force the piston down on the power stroke

5. a. First stroke--Intake

1) Piston moves down

2) Exhaust valve closed

3) Intake valve open

b. Second stroke--Compression

1) Piston moves up

2) Intake and exhaust valve closed

c. Third stroke--Power (ignition)

1) Piston going down

2) Intake and exhaust valve closed

d. Fourth stroke--Exhaust

1) Piston moves up

2) Intake valve closed

3) Exhaust valve open

6. a. Four stroke cycle--Fires every other time piston reaches top dead center

b. Two stroke cycle--Fires each time piston reaches top dead center

7. a. Two-cycle

1) Produces a power stroke for each revolution of the crankshaft

2) Theoretically produces twice the power for the same size engine

3) Smoother running as power strokes occur at shorter intervals

b. Four-cycle

1) Heat problem is less due to each cylinder firing half as often

2) Does not use engine power to drive a blower to force air charge into the cylinder under pressure

3) Burned gasses are completely cleared from the cylinder, resulting in more power per power stroke

4) Exhaust valves or ports open later creating some gain in effective power

8. a, d, e, f, i, l

DIESEL FUELS
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to discuss the characteristics of high cetane fuels and arrange in order the operating principles that describe the diesel fuel combustion cycle. The student should also be able to list two important considerations when storing diesel fuel and select the methods used to protect fuel quality. This knowledge will be evidenced by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with diesel fuels to the correct definitions.
2. Arrange in order the operating principles that describe the diesel fuel combustion cycle.
3. Match the properties of diesel fuel to the correct definitions.
4. List crude oil by-products.
5. Discuss the characteristics of high cetane fuels.
6. Name two grades of commercial diesel fuel meeting ASTM standards.
7. Distinguish between the cause of diesel ignition knock and the cause of gasoline ignition knock.
8. List three most likely causes of black smoke from a diesel exhaust.
9. List two most likely causes of white smoke from a diesel exhaust.
10. List two important considerations when storing diesel fuel.
11. Select the methods and rules used to protect fuel quality.
12. Select the number of feet required for safe spacing of diesel fuel storage tanks.

DIESEL FUELS
UNIT II

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information sheet.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Take student on tour of fuel storage facilities.

G. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Diesel Combustion Cycle
2. TM 2--ASTM Limiting Requirements for Diesel Fuels
3. TM 3--Safe Spacing of Storage Tanks

D. Test

E. Answers to test

II. References:

A. Toboldt, Bill. *Diesel: Fundamentals, Service, Repair.* South Holland, Illinois: Goodheart-Willcox Company, 1973.

B. *Fundamentals of Service: Fuels, Lubricants, and Coolants.* Moline, Illinois: Deere and Company, 1970.

DIESEL FUELS
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Crude oil--Mixture of hydrocarbons in natural state

B. Hydrocarbons--Compounds consisting of hydrogen and carbon

C. ASTM--American Society of Testing Materials

D. Volatility--Ability of a liquid to change into a vapor when heated

E. No. 1-D diesel fuel--ASTM classification of volatile fuel oils from kerosene to intermediate distillates

F. No. 2-D diesel fuel--Class of distillate gas oils of lower volatility than kerosene

II. Diesel fuel combustion cycle (Transparency 1)

A. Air only enters cylinder

B. Air is compressed

C. Fuel is sprayed into combustion chamber

D. Fuel-air ignites from heat of compression

III. Properties of diesel fuel and definitions

A. Heat value--Amount of power fuel will provide when burned

B. Specific gravity--Ratio of density of fuel (oil) to density of water

C. Flash point--Oil temperature at which flammable vapor driven off will ignite from an open flame

D. Cetane number--Ease with which the fuel will ignite expressed in numbers

(NOTE: Commercial diesel fuel cetane numbers range from 33 to 64.)

E. Carbon residue--Matter left after evaporation and chemical decomposition

F. Sulfur content--Causes corrosion and deposit formations in an engine

G. Ash--Unburnable residue in the form of soluble metallic soaps and abrasive solids

INFORMATION SHEET

H. Viscosity--Resistance of a liquid to flow

I. Pour point--Lowest temperature at which fuel ceases to flow

IV. Crude oil by-products (Transparency 2)

(NOTE: These by-products are listed in the order they are given off.)

A. Natural gas

(NOTE: This natural gas is used for homes, industry, and some engines.)

B. High octane aviation gas

C. Automotive gasoline

D. Finished kerosene

E. Domestic heating oil

F. Hydrocarbon gases

(NOTE: These raw materials are used in the manufacture of: high octane gasoline, synthetic rubber, plastics, paints and varnishes, alcohols and solvents, explosives, and many other products.)

G. Industrial fuel oil (diesel fuel)

H. Finished lubricating oils

I. Wax (paraffin)

J. Gas oil

K. Coke

L. Asphalt

(NOTE: As crude oil is refined, approximately 44 percent is gasoline, 36 percent is fuel oil, and the balance is kerosene, lubricants, and by-products.)

V. Characteristics of high cetane fuel

A. Permits engine start at lower air temperatures

B. Provides faster engine warm-up

C. Reduces the rate of formation of varnish and carbon deposits

D. Eliminates combustion roughness or carbon knock

INFORMATION SHEET

VI. Commercial diesel fuels meeting ASTM standards (Transparency 3)

A. No. 1-D

B. No. 2-D

VII. Causes of ignition knock

A. Diesel--Due to fuel igniting too slowly

(NOTE: Diesel fuel must burn fast.)

B. Gasoline--Due to fuel burning too fast and uneven explosions

(NOTE: Gasoline must burn evenly.)

VIII. Causes of black smoke from a diesel exhaust

A. Faulty fuel injection

B. Overfueling

C. Restricted air intake

IX. Causes of white smoke from a diesel exhaust

A. Unburned fuel

B. Partially burned fuel

X. Storing diesel fuel

A. Keep fuel free of dirt and water

B. Avoid gum deposits

XI. Methods and rules used to protect fuel quality

(NOTE: The fuel injection system on a diesel engine is fitted with parts that are held within millionths of an inch clearance. Very fine dirt particles soon ruin the parts and cause an expensive repair job. Water, even extremely small amounts, causes corrosion which ruins the highly polished surfaces of the injection system components.)

A. Do not let water collect on top of fuel barrels or storage tank

(NOTE: Water retained on the tank tends to rust the outside of the drum and as fuel is drawn from the tank, water may be drawn through the air vent directly into your fuel supply.)

INFORMATION SHEET

B. Do not use an open container to transfer fuel from the storage tank to the machine tank

(NOTE: This greatly increases the chance for dirt to enter the fuel tank. Equip the aboveground tank with a pump and hose or a gravity hose to transfer fuel. Be sure to cap the end of the hose nozzle while the hose is not in use.)

C. Do not store diesel fuel in a galvanized tank

(NOTE: When diesel fuel is stored in a galvanized tank, the fuel reacts with the galvanized finish, causing powdering particles to form. They soon clog the fuel filters on a diesel engine. Using a steel tank will avoid this.)

D. Do not use a tank formerly used for gasoline storage

(NOTE: Fine rust and dirt particles that settled out of gasoline and accumulated on the bottom of the tank mix readily with diesel fuel and may remain suspended in it until drawn from the tank.)

E. Do not let the suction pipe to the fuel pump extend to the bottom of the storage tank

(NOTE: This permits the pump to pick up water and sediment that has settled out of the fuel. The end of the pipe should be 3 to 4 inches from the bottom. If possible, slope the tank away from the pipe or outlet valve.)

F. Always drain the storage tank before refilling and clean the tank regularly

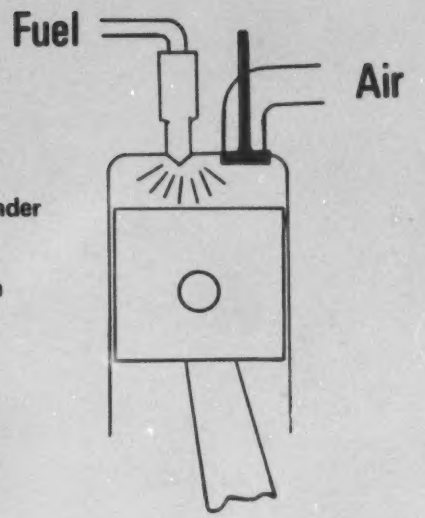
(NOTE: This will prevent the dirt and water residue from rising high enough to be drawn out with the fuel.)

XII. Safe spacing of fuel tanks (Transparency 4)

A. Forty feet from nearest building for aboveground tanks

B. One foot from nearest building for underground tanks

Diesel Combustion Cycle

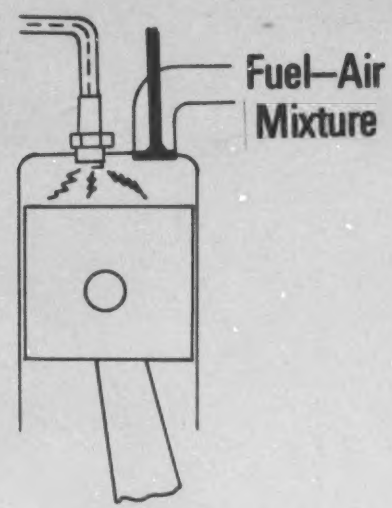


1. Air Only Enters Cylinder
2. Air is Compressed
3. Fuel is Sprayed in
4. Fuel -Air Ignites from Heat of Compression

Average Compression Ratio:

16 to 1

Diesel



1. Fuel-Air are Mixed in Carburetor
2. Mixture Enters Cylinder and is Compressed
3. Spark Ignites the Mixture

Average Compression Ratio:

8 to 1

Gasoline

ASTM Limiting Requirements for Diesel Fuels

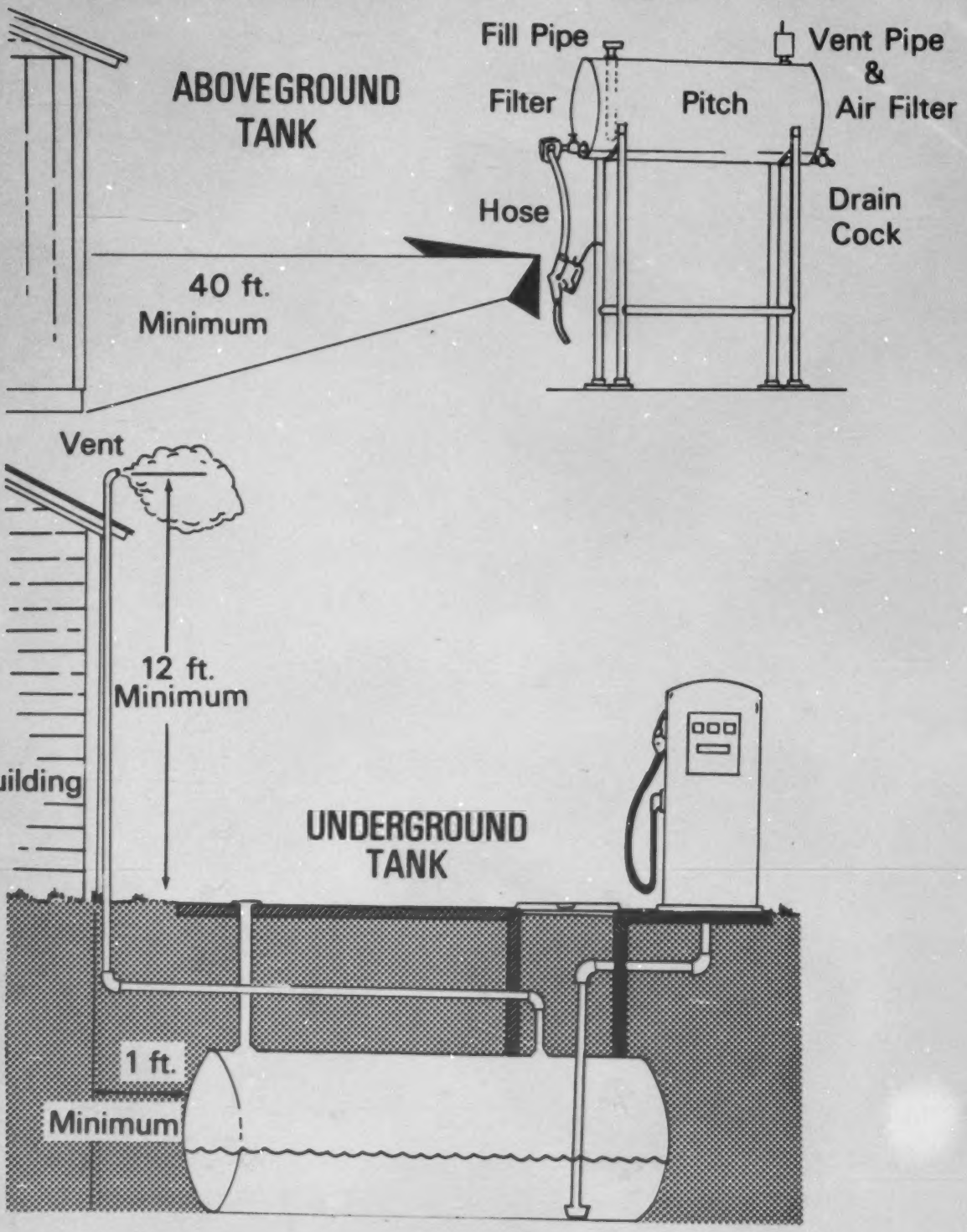
Diesel Fuel ***	Flash Point, °F.	Pour Point, °F.	Water and Sediment, % vol.	Carbon Residue on 10% Residuum, %	Ash, % wt.	90% Distillation Temperature, °F.		Viscosity at 100°F, Centistokes		Sulfur % wt.	Copper Strip Corrosion	Cetane Number
	Min.	Max.	Max.	Max.	Max.	Min.	Max.	Min.	Max.	Max.	Max.	Min.
No. 1-D	100 or legal	*	Trace	0.15	0.01	—	550	1.4	2.5	0.50	No. 3	40
No. 2-D	125 or legal	*	0.05	0.35	0.01	540**	640	2.0**	4.3	0.50	No. 3	40

*For cold weather operation, the pour point should be specified 10°F. below the ambient temperature at which the engine is to be operated except where fuel oil heating facilities are provided.

**When pour point less than 0°F. is specified, the minimum viscosity shall be 1.8 cs and the minimum of 90% point shall be waived.

***A diesel fuel of low volatility, No. 4-D, is recommended only for low- and medium-speed engines.

Safe Spacing of Storage Tanks



DIESEL FUELS
UNIT II

NAME _____

TEST

1. Match the terms on the right to the correct definitions.

_____a. Mixture of hydrocarbons in natural state	1. No. 2-D diesel fuel
_____b. Compounds consisting of hydrogen and carbon	2. ASTM
_____c. American Society of Testing Materials	3. Hydrocarbons
_____d. ASTM classification of volatile fuel oils from kerosene to intermediate distillates	4. Crude oil
_____e. Class of distillate gas oils of lower volatility than kerosene	5. Volatility
_____f. Ability of a liquid to change into a vapor when heated	6. No. 1-D diesel fuel

2. Arrange in order the operating principles that describe the diesel fuel combustion cycle.

_____a. Air only enters cylinder

_____b. Fuel-air ignites from heat of compression

_____c. Air is compressed

_____d. Fuel is sprayed into the combustion chamber

3. Match the properties of diesel fuel on the right to the correct definitions.

_____a. Amount of power fuel will provide when burned	1. Carbon residue
_____b. Ratio of density of fuel (oil) to density of water	2. Viscosity
_____c. Oil temperature at which flammable vapor driven off will ignite from an open flame	3. Ash
_____d. Ease with which fuel will ignite expressed in numbers	4. Pour point

_____e. Matter left after evaporation and chemical decomposition

_____f. Causes corrosion and deposit formations in an engine

_____g. Unburnable residue in the form of soluble metallic soaps and abrasive solids

_____h. Resistance of a liquid to flow

_____i. Lowest temperature at which fuel ceases to flow

5. Heat value
6. Specific gravity
7. Flash point
8. Sulfur content
9. Cetane number

4. List six crude oil by-products.

a.

b.

c.

d.

e.

f.

5. Discuss the characteristics of high cetane fuels.

6. Name two grades of commercial diesel fuel that meet ASTM standards.

a.

b.

7. Distinguish between the cause of diesel ignition knock and the cause of gasoline ignition knock by placing an "X" next to the cause of diesel ignition knock.

_____a. Due to fuel burning too fast and uneven explosions

_____b. Due to fuel igniting too slowly

8. List three most likely causes of black smoke from a diesel exhaust.

   a.

   b.

   c.

9. List two most likely causes of white smoke from a diesel exhaust.

   a.

   b.

10. List two important considerations when storing diesel fuel.

    a.

    b.

11. Select the methods and rules used to protect fuel quality by placing an "X" in the appropriate blanks.

    _____a. Store fuel in a galvanized tank

    _____b. Always drain the storage tank before refilling and clean the tank regularly

    _____c. Use tank formerly used for gasoline when needed

    _____d. Do not let the suction pipe to the fuel pump extend to the bottom of the storage tank

    _____e. Use an open container to transfer fuel from tank to machine

    _____f. Do not let water collect on top of fuel barrels or storage tanks

12. Select the number of feet required for safe spacing of storage tanks from buildings by placing the correct number in the appropriate blanks.

    _____a. Underground tanks

    _____b. Aboveground tanks

    1. 1 foot
    2. 2 feet
    3. 5 feet
    4. 30 feet
    5. 40 feet
    6. 50 feet

DIESEL FUELS
UNIT II

ANSWERS TO TEST

1. a. 4
   b. 3
   c. 2
   d. 6
   e. 1
   f. 5

2. a. 1
   b. 4
   c. 2
   d. 3

3. a. 5
   b. 6
   c. 7
   d. 9
   e. 1
   f. 8
   g. 3
   h. 2
   i. 4

4. Any six of the following:
   a. Natural gas
   b. High octane aviation gas
   c. Automotive gasoline
   d. Finished kerosene
   e. Domestic heating oil
   f. Hydrocarbon gases
   g. Industrial fuel oil (diesel fuel)
   h. Finished lubricating oils
   i. Wax (paraffin)
   j. Gas oil
   k. Coke
   l. Asphalt

5. Discussion should include:
   a. Permits engine start at lower air temperatures
   b. Provides faster engine warm-up
   c. Reduces the rate of formation of varnish and carbon deposits
   d. Eliminates combustion roughness or carbon knock
6. a. No. 1-D
   b. No. 2-D
7. b
8. a. Faulty fuel injection
   b. Overfueling
   c. Restricted air intake
9. a. Unburned fuel
   b. Partially burned fuel
10. a. Keep fuel free of dirt and water
    b. Avoid gum deposits
11. b, d, f
12. a. 1
    b. 5

ENGINE LUBRICANTS
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to list functions of engine oils and match oil additives to their functions. The student should also be able to name oil contaminants and discuss ways to avoid oil contamination. This knowledge will be evidenced by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with lubricants to the correct definitions.
2. List four functions of engine oil.
3. Select the characteristics of a good engine oil.
4. Discuss oil ratings and classifications.
5. Explain the SAE viscosity number.
6. Explain the API classification system.
7. Name five oil contaminants.
8. Match oil additives to their functions.
9. Select factual statements about oil.
10. List general rules for selection and use of oils for best engine performance.
11. Discuss ways to avoid oil contamination.

ENGINE LUBRICANTS
UNIT III

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information sheet.

C. Make transparency.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Invite speakers from industry to talk on lubricants.

G. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1-SAE Viscosity
2. TM 2-SAE Viscosity (Continued)

D. Test

E. Answers to test

II. Reference--*Fundamentals of Service: Fuels, Lubricants, and Coolants.* Moline, Illinois: Deere and Company, 1970.

ENGINE LUBRICANTS
UNIT III

INFORMATION SHEET

I. Terms and definitions

A. Additives--Certain properties added to oil to provide extra performance

B. Multi-grade oil--Oils compounded to behave as light oils at cold temperatures and heavy oils at warm temperatures

C. SAE--Society of Automotive Engineers

D. API--American Petroleum Institute

E. MIL--Oil specifications prepared by the Ordnance Department of the Military Forces

F. ASTM--American Society for Testing Materials

G. Viscosity--A measure of the fluidity of an oil at a given temperature

H. Viscometer--Instrument used to measure the length of time in seconds required for a specified volume of oil to flow through a small orifice when the oil is brought to a specified temperature

II. Functions of engine oil

A. Reduces friction and wear

B. Cools moving parts

C. Helps seal cylinders

D. Keeps parts clean

III. Characteristics of good engine oil

A. Keeps a protective film on moving parts

B. Resists breakdown at high temperatures

C. Resists corrosion and rusting

D. Prevents carbon build-up

E. Prevents sludge formation

INFORMATION SHEET

F. Flows easily at low temperatures

G. Resists foaming

H. Resists breakdown after long use

IV. Oil ratings and classification

A. SAE--Viscosity established by Society of Automotive Engineers

B. API--Service classification established by American Petroleum Institute

C. MIL--Specifications prepared by Ordnance Department of the U.S. Army, Navy, and Air Force

D. ASTM--Engine sequence tests whose procedures are adopted by the American Society for Testing Materials

V. SAE viscosity number (Transparency 1)

A. Oils vary in viscosity as temperatures change

(NOTE: Oil becomes more fluid as temperatures increase and less fluid as temperatures decrease.)

B. Lighter oils for winter use are specified at 0°F and carry a 5w, 10w or 20w symbol

(NOTE: Specifications are determined by time of flow through an instrument, such as a Saybolt viscometer, in seconds.)

C. Heavier oils are specified at 210°F and carry a 20, 30, 40, or 50 viscosity number

(NOTE: Compounded oils called multi-grade behave as light oils in cold temperatures and heavier oils at high temperatures, for example 10w-40 can replace four single grade oils.)

VI. API classification system

A. Joint effort of API, ASTM, and SAE organizations

B. Attempts to clarify oil specifications and oil qualities between the engine manufacturer, the petroleum industry, and the customer

VII. Oil contaminants

A. Foreign particles

B. Water

C. Antifreeze

INFORMATION SHEET

D. Fuel

E. Oxidation

VIII. Oil additives and their functions

(NOTE: Most oils already have these additives.)

A. Anti-corrosion--Helps prevent failure of alloy bearings from corrosive acids caused by combustion

B. Oxidation inhibitor--Prevents acid, varnish, and sludge formations

(NOTE: Oxidation causes oil to thicken.)

C. Anti-rust--Prevents rusting of metal parts during storage or downtime

D. Viscosity index improver--Helps oil give top lubricating protection at both high and low temperatures

E. Pour point depressant--Prevents wax crystals from congealing in cold weather and forming clumps

F. Extreme pressure--Assures lubrication where extreme pressures between close tolerances are encountered

G. Detergent-dispersant--Helps keep metal surfaces clean and prevents deposit formation

H. Foam inhibitor--Helps prevent air bubbles which would restrict lubrication

(NOTE: Fast circulation causes oil to foam.)

IX. Factual statements about oil

A. Oil becomes unfit for further use as it absorbs contaminants and as additives are depleted

B. Multi-viscosity oils are not always preferred

C. Black oil does not mean time for an oil change

D. Buy quality oil filters as recommended by machine operator's manual

E. Oil oxidation results in thicker oil

INFORMATION SHEET

F. Using a light oil until consumption increases, and then switching to a heavier oil, is not a good practice

G. Following operator's manual recommendations is critical to insure good performance

X. Selection and use of oils for best engine performance

A. Use brands which meet engine manufacturer's specifications

B. Drain and change at recommended intervals

C. Select oils which have been performance tested

D. Never mix oils of various MIL specifications

E. Bring engine up to normal operating temperature each time it is used

F. Keep oil containers covered, sealed, and protected to prevent contamination

XI. Ways to avoid oil contamination

A. Drain oil at recommended intervals

B. Use clean oil containers and work habits

C. Replace or clean filters before they become plugged

SAE Viscosity

SAE CRANKCASE OIL CLASSIFICATION

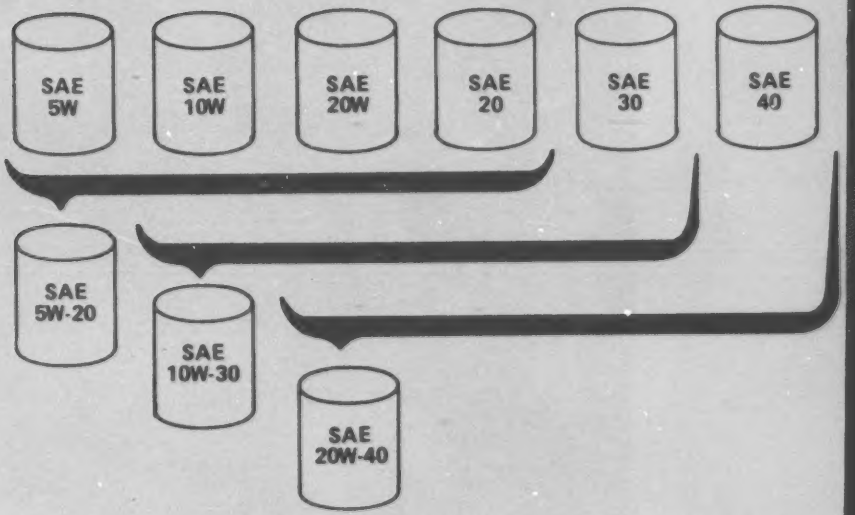
SAE Viscosity Number	Time of Flow Through Saybolt Viscometer in Seconds			
	at 0°F.		at 210°F.	
	Min.	Max.	Min.	Max.
5W	—	6,000	—	—
10W	6,000 (Note A)	less than 12,000	—	—
20W	12,000 (Note B)	48,000	—	—
20	—	—	45	less than 58
30	—	—	58	less than 70
40	—	—	70	less than 85
50	—	—	85	110

Note A. Minimum viscosity at 0°F may be waived provided viscosity at 210°F is not below 40 seconds, Saybolt Universal.
Note B. Minimum viscosity at 0°F may be waived provided viscosity at 210°F is below 45 seconds, Saybolt Universal.

SAE Viscosity
(Continued)

Saybolt
Viscometer

Kinematic
Viscometer



A Multi-Viscosity Oil Can Replace Several Single-Viscosity Oils (When Recommended)

ENGINE LUBRICANTS
UNIT III

NAME _____

TEST

1. Match the terms on the right to the correct definitions.

_____a. Certain properties added to oil to provide extra performance

_____b. Oils compounded to behave as light oils at cold temperatures and heavy oils at warm temperatures

_____c. Society of Automotive Engineers

_____d. American Petroleum Institute

_____e. Oil specifications prepared by the Ordnance Department of the Military Forces

_____f. American Society for Testing Materials

_____g. A measure of the fluidity of an oil at a given temperature

_____h. Instrument used to measure the length of time in seconds required for a specified volume of oil to flow through a small orifice when the oil is brought to a specified temperature

1. SAE
2. Viscosity
3. API
4. MIL
5. Viscometer
6. ASTM
7. Multi-grade oil
8. Additives

2. List four functions of engine oil.

a.

b.

c.

d.

3. Select the statements which describe a characteristic of a good engine oil by placing an "X" in the appropriate blanks.

_____a. Keeps a protective film on moving parts

_____b. Resists breakdown at high temperatures

_____c. Resists corrosion and rusting

_____d. Prevents carbon build-up

_____e. Prevents sludge formation

_____f. Flows easily at low temperatures

_____g. Flows easily at high temperature

_____h. Resists foaming

_____i. Resists breakdown after long use

4. Discuss oil ratings and classifications.

   a. SAE--

   b. API--

   c. MIL--

   d. ASTM--

5. Explain the SAE viscosity number.

6. Explain the API classification system.

7. Name five oil contaminants.

a.

b.

c.

d.

e.

8. Match the oil additives on the right to their functions.

_____a. Helps prevent failure of alloy bearings from corrosive acids caused by combustion

_____b. Prevents acid, varnish, and sludge formations

_____c. Prevents rusting of metal parts during storage or downtime

_____d. Helps oil give top lubricating protection at both high and low temperatures

_____e. Prevents wax crystals from congealing in cold weather and forming clumps

_____f. Assures lubrication where extreme pressures between close tolerances are encountered

_____g. Helps keep metal surfaces clean and prevents deposit formation

_____h. Helps prevent air bubbles which would restrict lubrication

1. Anti-rust
2. Oxidation inhibitor
3. Anti-corrosion
4. Viscosity index improver
5. Pour point depressant
6. Extreme pressure
7. Foam inhibitor
8. Detergent-dispersant

9. Select the factual statements about oil by placing an "X" in the appropriate blanks.

_____a. Oil becomes unfit for further use as it absorbs contaminants and as additives are depleted

_____b. Multi-viscosity oils are not always preferred

_____c. Black oil does not mean time for an oil change

_____d. Buy quality oil filters as recommended by machine operators manual

_____e. Oil oxidation results in thicker oil

_____f. Using a light oil until consumption increases, and then switching to a heavier oil, is not a good practice

_____g. Following operator's manual recommendations is critical to insure good performance

10. List five general rules for selection and use of oils for best engine performance.

a.

b.

c.

d.

e.

11. Discuss ways to avoid oil contamination.

ENGINE LUBRICANTS
UNIT III

ANSWERS TO TEST

1. a. 8 e. 4
   b. 7 f. 6
   c. 1 g. 2
   d. 3 h. 5

2. a. Reduces friction and wear
   b. Cools moving parts
   c. Helps seal cylinders
   d. Keep parts clean

3. a, b, c, d, e, f, h, i

4. Discussion should include:
   a. SAE--Viscosity established by Society of Automotive Engineers
   b. API--Service classification established by American Petroleum Institute
   c. MIL--Specifications prepared by Ordnance Department of U.S. Army, Navy, and Air Force
   d. ASTM--Engine sequence tests whose procedures are adopted by the American Society for Testing Materials

5. Explanation should include:
   a. Oils vary in viscosity as temperatures change
   b. Lighter oils for winter use are specified at 0°F and carry a 5w, 10w, or 20w symbol
   c. Heavier oils are specified at 210°F and carry a 20, 30, 40, or 50 viscosity number

6. Explanation should include:
   a. Joint effort of API, ASTM, and SAE
   b. Attempts to clarify oil specifications and oil qualities between the engine manufacturer, petroleum industry, and the customer

7. a. Foreign particles
   b. Water
   c. Antifreeze
   d. Fuel
   e. Oxidation

8. a. 3
   b. 2
   c. 1
   d. 4
   e. 5
   f. 6
   g. 8
   h. 7

9. a, b, c, d, e, f, g

10. Any five of the following:
   a. Use brands which meet engine manufacturer's specifications
   b. Drain and change at recommended intervals
   c. Select oils which have been performance tested
   d. Never mix oils of various MIL specifications
   e. Bring engine up to normal operating temperature each time it is used
   f. Keep oil containers covered, sealed, and protected to prevent contamination

11. Discussion should include any two of the following:
   a. Drain oil at recommended intervals
   b. Use clean oil containers and work habits
   c. Replace or clean filters before they become plugged

COOLANTS
UNIT IV

UNIT OBJECTIVE

After completion of this unit, the student should be able to list the advantages and disadvantages of water as a coolant. He should also be able to discuss the requirements of a good antifreeze and list the preventive maintenance procedures to follow in maintaining a cooling system. This knowledge will be evidenced by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with cooling systems to the correct definitions.
2. Name two types of cooling systems used on modern engines.
3. Match the parts of a liquid cooling system to the correct functions.
4. List advantages of water as a coolant.
5. List disadvantages of water as a coolant.
6. List requirements of a good antifreeze.
7. Name two types of antifreeze used most in modern engines.
8. Match the coolant to the temperature at which it boils.
9. List preventive maintenance procedures to follow in maintaining a cooling system.

COOLANTS
UNIT IV

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information sheet.

C. Make transparency.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures for measuring the antifreeze in a cooling system.

G. Discuss cooling system conditioners.

H. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency master: TM 1--Parts of a Liquid Cooling System

D. Test

E. Answers to test

II. Reference--*Fundamentals of Service: Fuels, Lubricants, and Coolants.* Moline, Illinois: Deere and Co., 1970.

COOLANTS
UNIT IV

INFORMATION SHEET

I. Terms and definitions

A. Inhibitor--Material used in coolants to restrict or prevent corrosion of metal parts

B. Antifreeze--Material added to coolant to prevent freezing

C. Coolant--Liquid that absorbs and transfers heat to maintain normal engine operating temperature

D. Permanent antifreeze--Liquid solution which contains properties that will not readily boil away

II. Types of cooling systems used on modern engines

A. Air

B. Liquid

III. Parts of a liquid cooling system and their functions (Transparency 1)

A. Radiator--Releases heat to atmosphere; reservoir for enough liquid coolant to operate engine

B. Expansion tank--Separate tank in cooling system that allows for heat expansion of coolant

C. Pressure cap--Relieves pressure from too much heat; lets in air pressure as liquid cools

(NOTE: A pressurized cooling system raises the boiling temperatures of coolants about 2° for each pound of pressure.)

D. Fan--Forces cooling air through radiator core to more quickly dissipate heat

E. Fan belt--Transmits power from engine crankshaft to drive fan and water pump

F. Water pump--Circulates coolant through the system

G. Thermostat--Controls the flow of coolant to radiator to maintain correct operating temperatures

H. Hoses--Flexible connections between engine and other parts of cooling system

INFORMATION SHEET

I. Coolant--Median which carries away excess heat from engine

J. Coolant filter--Used in some engines to soften the water and remove dirt

IV. Advantages of water as a coolant

A. Plentiful and cheap

B. Absorbs heat well

C. Circulates freely

D. Harmless to handle

V. Disadvantages of water as a coolant

A. Will freeze at 32°F

B. Can corrode metal parts

C. Can leave deposits

D. Will evaporate

VI. Requirements of a good antifreeze

A. Prevents freezing

B. Inhibits rust and corrosion

C. Chemically stable

D. Nonconductor of electricity

E. Flows readily at all temperatures

F. Conducts heat readily

G. Resists foaming

VII. Types of antifreeze used most in modern engines

A. Alcohol base

B. Ethylene glycol base

INFORMATION SHEET

VIII. Boiling temperature of coolants

A. Alcohol base antifreeze--180°F

B. Water--212°F

C. Ethylene glycol base antifreeze--223°F

IX. Preventive maintenance procedures

A. Inspect for system deterioration

(NOTE: Pressure test the cooling system.)

(CAUTION: Do not exceed pressure cap limits.)

B. Prevent corrosion and deposits

C. Flush and clean system periodically

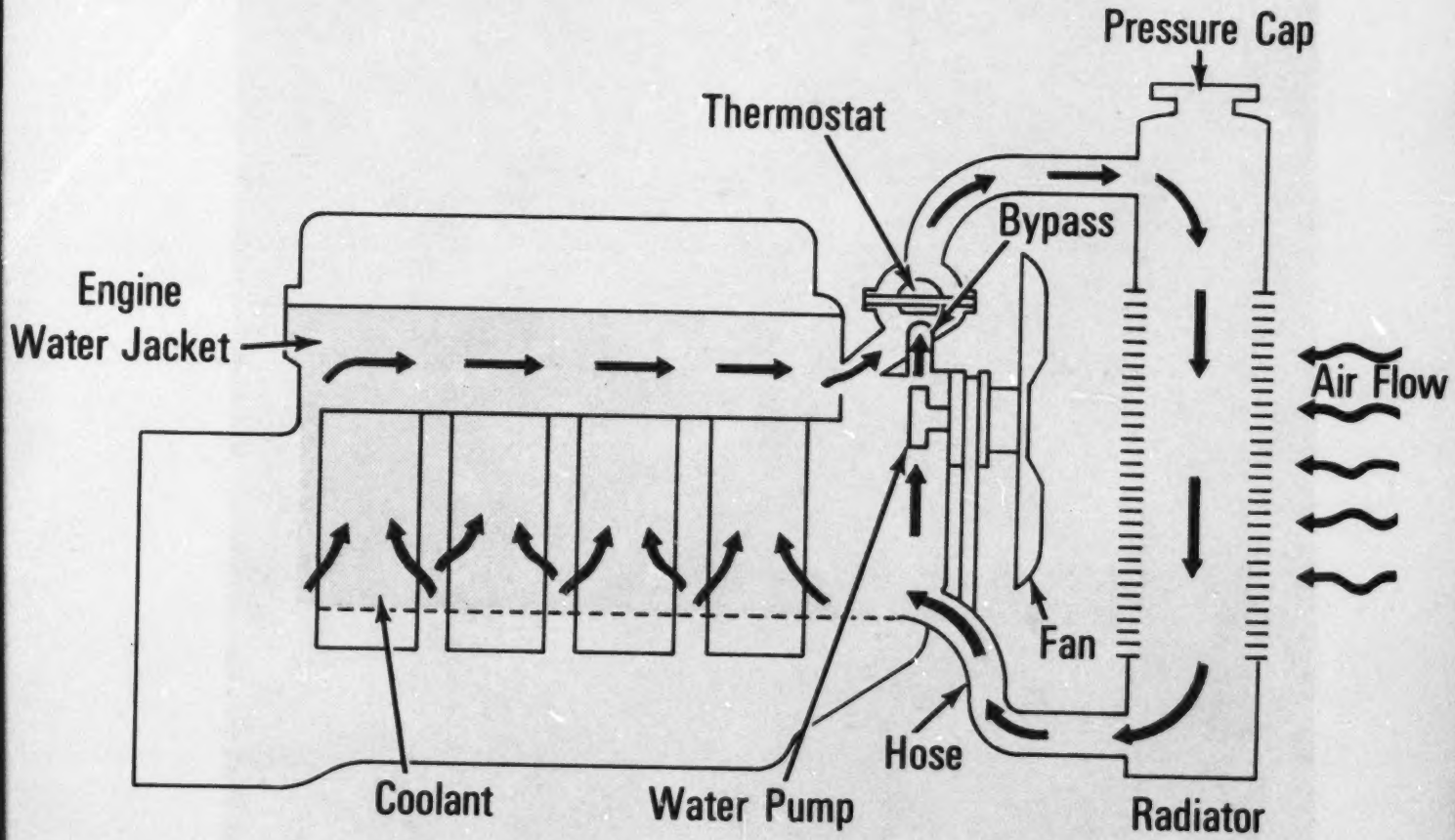
D. Lubricate water pump and fan, as required

E. Allow a hot engine to idle a few minutes before shutting it down

(NOTE: Idle speed allows temperatures of parts to equalize and prevents after boil of coolant.)

F. Check coolant as recommended in operator's manual

Parts of a Liquid Cooling System



COOLANTS
UNIT IV

NAME _____

TEST

1. Match the terms on the right to the correct definitions.

_____a.	Material used in coolants to restrict or prevent corrosion of metal parts	1.	Permanent antifreeze
_____b.	Material added to coolant to prevent freezing	2.	Antifreeze
_____c.	Liquid that absorbs and transfers heat to maintain normal engine operating temperature	3.	Coolant
_____d.	Liquid solution which contains properties that will not readily boil away	4.	Inhibitor

2. Name two types of cooling systems used on modern engines.

a.

b.

3. Match the parts of a liquid cooling system on the right to the correct functions.

_____a.	Releases heat to atmosphere; reservoir for enough liquid coolant to operate engine	1.	Thermostat
_____b.	Separate tank in cooling system that allows for heat expansion of coolant	2.	Pressure cap
_____c.	Relieves pressure from too much heat; lets in air pressure as liquid cools	3.	Fan
_____d.	Forces cooling air through radiator core to more quickly dissipate heat	4.	Radiator
_____e.	Circulates coolant through the system	5.	Coolant
_____f.	Transmits power from engine crankshaft to drive fan and water pump	6.	Fan belt

_____g. Controls the flow of coolant to radiator to maintain correct operating temperatures

_____h. Flexible connections between engine and other parts of cooling system

_____i. Median which carries away excess heat from engine

_____j. Used in some engines to soften the water and remove dirt

7. Water pump
8. Hoses
9. Coolant filter
10. Expansion tank

4. List three advantages of water as a coolant.

a.

b.

c.

5. List three disadvantages of water as a coolant.

a.

b.

c.

6. List five requirements of a good antifreeze.

a.

b.

c.

d.

e.

7. Name two types of antifreeze used most in modern engines.

   a.

   b.

8. Match the coolant on the right to the temperature at which it boils.

_____a. 223°F	1. Alcohol base antifreeze
_____b. 180°F	2. Water
_____c. 212°F	3. Ethylene glycol base antifreeze

9. List four preventive maintenance procedures to follow in maintaining a cooling system.

   a.

   b.

   c.

   d.

COOLANTS
UNIT IV

ANSWERS TO TEST

1. a. 4
   b. 2
   c. 3
   d. 1
2. a. Air
   b. Liquid
3. a. 4
   b. 10
   c. 2
   d. 3
   e. 7
   f. 6
   g. 1
   h. 8
   i. 5
   j. 9
4. Any three of the following:
   a. Plentiful and cheap
   b. Absorbs heat well
   c. Circulates freely
   d. Harmless to handle
5. Any three of the following:
   a. Will freeze at 32°F
   b. Can corrode metal parts
   c. Can leave deposits
   d. Will evaporate

6. Any five of the following:
   a. Prevents freezing
   b. Inhibits rust and corrosion
   c. Chemically stable
   d. Nonconductor of electricity
   e. Flows readily at all temperatures
   f. Conducts heat readily
   g. Resists foaming
7. a. Alcohol base
   b. Ethylene glycol base
8. a. 3
   b. 1
   c. 2
9. Any four of the following:
   a. Inspect for system deterioration
   b. Prevent corrosion and deposits
   c. Flush and clean system periodically
   d. Lubricate water pump and fan, as required
   e. Allow a hot engine to idle a few minutes before shutting it down
   f. Check coolant as recommended in operator's manual

BEARINGS
UNIT V

UNIT OBJECTIVE

After completion of this unit, the student should be able to name types of bearings and list their functions. The student should also be able to list factors influencing the distribution of lubricant to the bearings, list causes of bearing failure and demonstrate correct procedures for removal and installation of plain and anti-friction bearings. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with bearings to the correct definitions.
2. List four functions of bearings.
3. Name two basic types of bearings.
4. Discuss load forces on bearings.
5. Match the types of bearings to the advantages and disadvantages.
6. Match the illustrations of plain bearings to the correct names.
7. List materials from which bearings may be constructed.
8. List three factors influencing the distribution of lubricant to the bearings.
9. Name common methods of lubricating bearings.
10. List causes of bearing failure in plain bearings.
11. List four reasons for bearing crush.
12. Name three types of anti-friction bearings.
13. List three conditions that determine the load carrying capacity of anti-friction bearings.
14. Name four types of ball bearing races.
15. List four designs of ball bearings.

16. List five types of roller bearings.

17. Name two types of needle bearings.

18. Discuss mountings for anti-friction bearings.

19. Select bearing maintenance tips.

20. Demonstrate the ability to:

    a. Remove and install a plain bearing.

    b. Remove and install an anti-friction bearing.

    c. Check preload bearing setting, spring scale method.

BEARINGS
UNIT V

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheets.

F. Demonstrate and discuss the procedures outlined in the job sheets.

G. Discuss typical adjusting (preloading) devices for tapered roller bearings to include slotted hex nut and cotter pin, lock nuts and torqued washer, shims, and threaded cup follower.

H. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete job sheets.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Basic Types of Bearings

2. TM 2--Load Forces

3. TM 3--Types of Plain Bearings
4. TM 4--Oil Groove Design
5. TM 5--Methods of Bearing Lubrication
6. TM 6--Causes of Bearing Failure
7. TM 7--Types of Ball Bearing Races
8. TM 8--Ball Bearing Designs
9. TM 9--Basic Types of Roller and Needle Bearings
10. TM 10--Typical Ball Bearing Mountings
11. TM 11--Typical Roller Bearing Mountings
12. TM 12--Typical Needle Bearing Mountings

D. Job sheets

1. Job Sheet #1--Remove and Install a Plain Bearing
2. Job Sheet #2--Remove and Install an Anti-Friction Bearing
3. Job Sheet #3--Check Preload Bearing Setting, Spring Scale Method

E. Test

F. Answers to test

II. Reference--*Fundamentals of Service: Bearings and Seals.* Moline, Illinois: Deere and Co., 1974.

BEARINGS
UNIT V

INFORMATION SHEET

I. Terms and definitions

A. Friction--Resistance to motion between two bodies in contact

B. Radial load--Force is directed sideways or perpendicular to the shaft

C. Axial load--Force is directed endways or horizontal to shaft

D. Races--Two hardened steel rings

E. Plastigage--Plastic thread which "crushes" to the exact clearance when measuring bearing clearance

F. Babbit--Alloy of lead, tin, antimony, and other metals

G. Plain bearing--Supporting surface for a wheel or shaft that provides a sliding contact between the mating surfaces

(NOTE: Plain bearings are also called bushings.)

H. Bearing crush--Each half of the bearing extends one or two thousandths of an inch beyond the bearing seat bore

I. Anti-friction bearing--Supporting surface for a wheel or shaft that provides a rolling contact between mating surfaces

J. Preloading--Adjustment of anti-friction bearing after being secured in the mounting

II. Functions of bearings

A. Support the moving part

B. Reduce friction

C. Reduce wear

D. Provide a replaceable wear surface

III. Basic types of bearings (Transparency 1)

A. Plain bearings

B. Anti-friction bearings

INFORMATION SHEET

IV. Load forces on bearings (Transparency 2)

A. Axial load forces are those forces directed endways

(NOTE: Thrust bearings are used to support the endways force.)

B. Radial load forces are those forces directed sideways or perpendicular to the shaft

V. Advantages and disadvantages of plain bearings and anti-friction bearings

A. Plain bearings (bushings)

1. Advantages

a. Require little space

b. Low in cost

c. Quiet operation

d. Rigid construction

2. Disadvantages

a. High friction operation

b. Require more frequent lubrication because they cannot be packed

B. Anti-friction bearings

1. Advantages

a. Low friction operation

b. Can be packed to reduce frequency of lubrication

c. More versatile, many designs

2. Disadvantages

a. Require more space

b. Noisier operation

c. Higher cost

d. Less rigidity

INFORMATION SHEET

VI. Types of plain bearings (Transparency 3)

A. Solid bearing or sleeve

B. Split bearing, rolled type

C. Thrust bearing

D. Split bearing with steel back lined with bronze or babbit

E. Split type constructed of wood, plastic, or rubber

F. Split bearing used for engine crankshaft

G. Solid bearing with fluted rubber structure

VII. Materials from which bearings may be constructed

A. Wood

B. Cast iron

C. Soft steel

D. Hard steel

E. Copper, brass, and bronze

F. Copper, lead

G. Babbit

H. Aluminum

I. Plastic

J. Rubber

VIII. Factors influencing the distribution of lubricant to the bearings (Transparency 4)

A. Oil grooves

B. Bearing clearance

C. Bearing surface compatibility

(NOTE: Bearing surface compatibility is determined by viscosity of the lubricant, speed of shaft rotation, and smoothness of the mating surfaces.)

INFORMATION SHEET

IX. Methods of lubricating bearings (Transparency 5)

A. Oil can

B. Grease gun

C. Central grease system

(NOTE: One plunger lubricates several grease fittings.)

D. Oil bath splash

E. Pressure feed system

X. Causes of bearing failure in plain bearings (Transparency 6)

A. Dirt

B. Lack of lubrication

C. Improper assembly

(NOTE: Improper assembly may result in too little or too much bearing crush, improper bearing clearance, or mislocated oil hole.)

D. Misalignment

E. Overloading

F. Corrosion

XI. Reasons for bearing crush

A. Greater heat dissipation

B. Insert is forced to seat solidly

C. Insures that the bearings remain round

D. Avoids any possible movement of the bearing in the seat

(NOTE: The amount of crush must not be excessive (.001" or .002") or the insert will be distorted when the cap is tightened. The bearing will buckle, and will result in increased friction and heat.)

XII. Types of anti-friction bearings (Transparency 1)

A. Ball

B. Roller

C. Needle

INFORMATION SHEET

XIII. Conditions that determine load carrying capacity of anti-friction bearings

A. Size of bearing

B. Number of rolling elements

C. Type of race

XIV. Types of ball bearing races (Transparency 7)

A. Conrad

B. Full type

C. Split race

D. Angular contact

XV. Designs of ball bearings (Transparency 8)

A. Radial load

B. Radial and thrust load

C. Self-aligning, radial load

D. Thrust load

XVI. Types of roller bearings (Transparency 9)

A. Radial load, straight roller

B. Radial and thrust load, tapered roller

C. Self-aligning, radial and thrust load, spherical roller

D. Self-aligning, radial and thrust load, concave roller

E. Thrust load

XVII. Types of needle bearings (Transparency 9)

A. Radial load

B. Thrust load

INFORMATION SHEET

XVIII. Mountings for anti-friction bearings (Transparency 10, 11, and 12)

A. Shape must not be distorted

B. Rolling elements must not be bound

C. Inner and outer races must be aligned

(NOTE: This is not necessary with self-aligning bearings.)

D. Axis of each bearing must be aligned with the other

(NOTE: The above condition applies when two or more bearings are mounted on the same shaft.)

E. Usually mounted with one race a press fit and the other a push fit

(NOTE: Normally the press fit race is pressed onto or into the rotating part and the push fit onto or into the stationary part. This rule of thumb is not true in every situation. Large bearings, tremendous loads, and high speeds may require both races to be pressed into place.)

F. Seals are used to retain lubricant and exclude dirt

XIX. Bearing maintenance tips

A. Work with clean approved tools, in clean surroundings

B. Clean outside of housings before exposing bearings

C. Handle bearings with clean, dry hands

D. Work on a metal or metal covered bench

E. Treat a used bearing as carefully as a new one, until the used one is proven to be defective

F. Use clean solvents and flushing oils

G. Lay bearings out on a clean surface

H. Protect disassembled bearings from dirt and moisture

I. Wipe bearings, if necessary, only with clean, lint-free rags

J. Keep bearings wrapped in oil-proof paper when not in use

K. Thoroughly clean the inside of housings before installing bearings

INFORMATION SHEET

L. Install new bearings as they come from the package, without washing, if they are received in a sealed container

M. Keep lubricants clean when applying them, and cover the containers when not in use

N. Don't spin uncleaned or dry bearings

O. Don't spin any bearing with compressed air

P. Don't use the same container for both cleaning and final rinse of used bearings

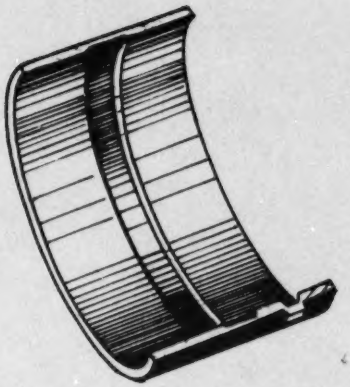
Q. Don't use gasolines

(CAUTION: The fumes may be injurious to health, as well as a fire hazard.)

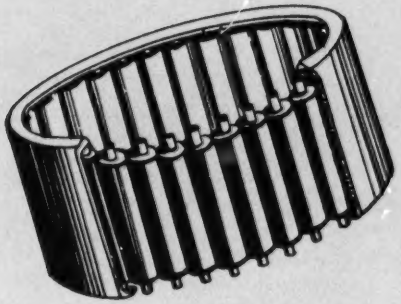
R. Don't use incorrect type or amount of lubricant

Basic Types Of Bearings

Split Bearing

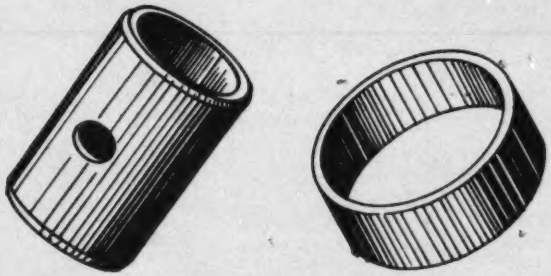


Needle Bearing



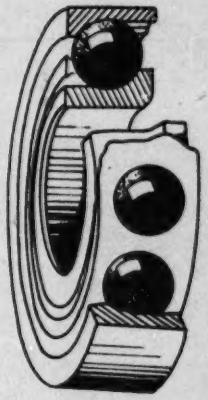
Plain Bearings (Bushings)

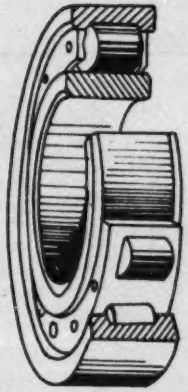
Anti-Friction Bearings



Plain Bearings

Ball Bearing

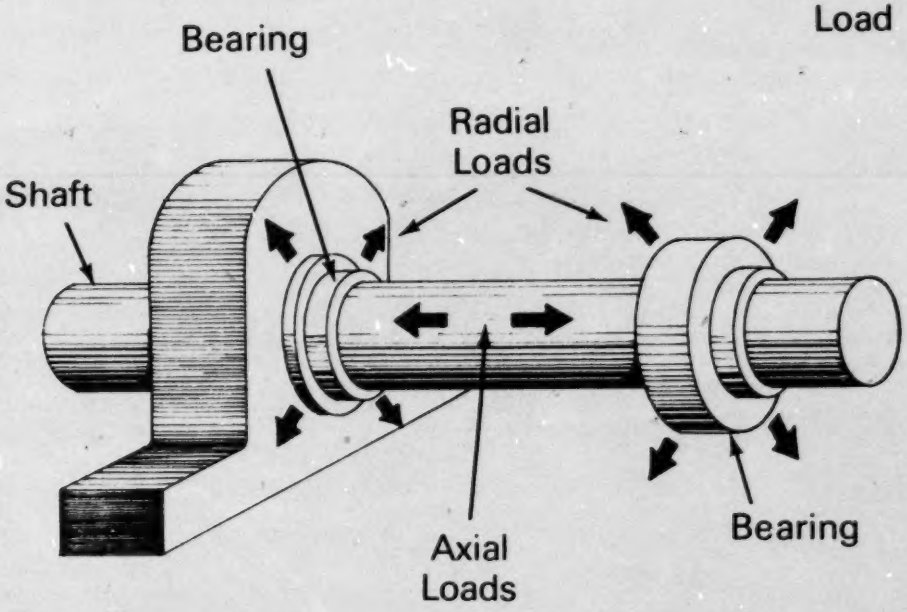


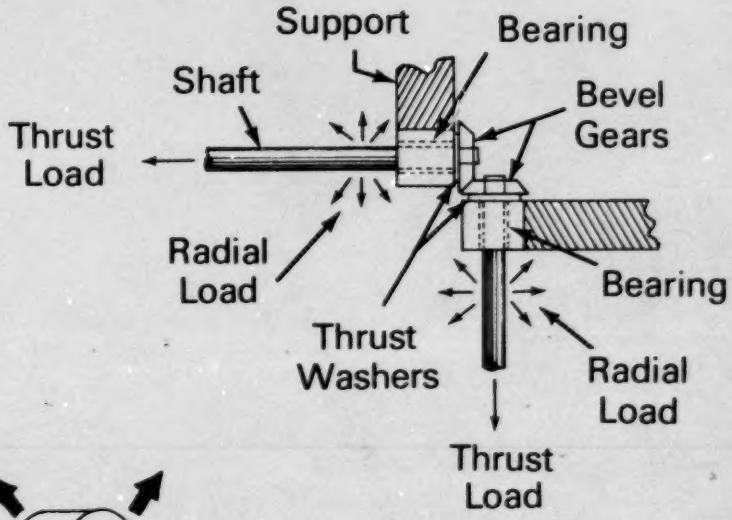


Roller Bearing

Load Forces

Thrust Washers Used With Radial-Load-Type Bearings

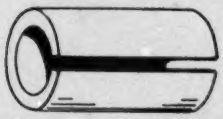




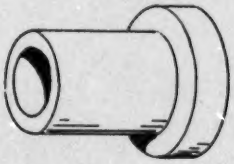
Load Forces Acting On Bearings

Types of Plain Bearings

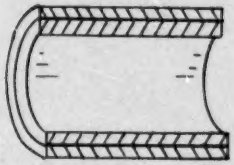
Solid Bearing
or Sleeve



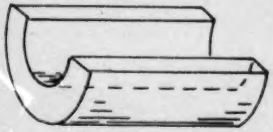
Split Bearing,
Rolled Type



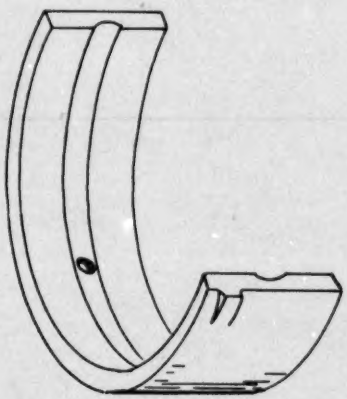
Thrust Bearing



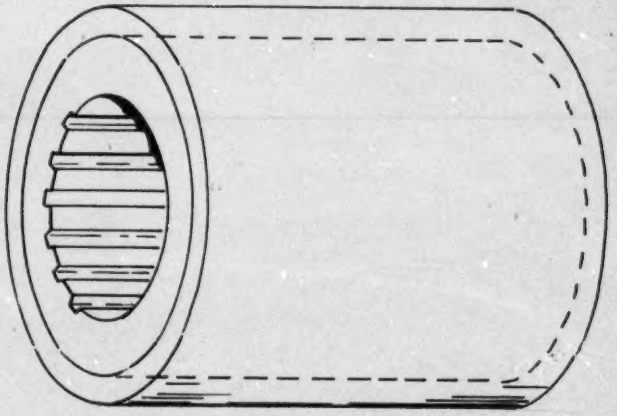
Split Bearing with
Steel Back Lined with
Bronze or Babbit



Split Type
Constructed
of Wood, Plastic,
or Rubber

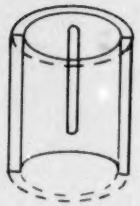


Split Bearing Used
for Engine Crankshaft



Solid Bearing with
Fluted Rubber Structure

Oil Groove Design



Used in General Applications

Also Used in General Applications

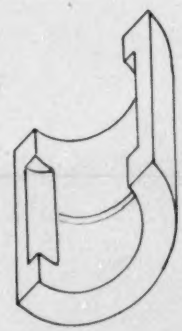
Used When Oil is Supplied Near End of Bearing

Used for Grease Lubrication

Also Used for Grease Lubrication

Used for Pulsating Loads with Limited Shaft Rotation

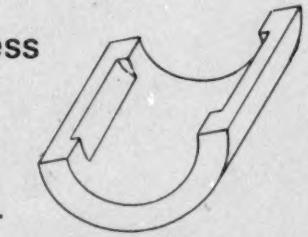
Used for Fractional Horsepower Motors



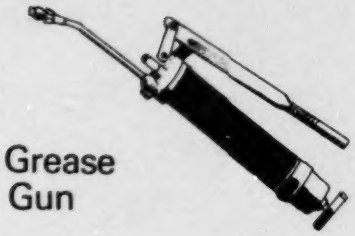
Circumferential Groove and Chamfered Recess Improves Oil Film Cooling. Used in Engine Bearings.

Feeder Groove and Axial Distributing Groove Used for Large, Slow Speed Bearings

Chamfered Recess in Split Bearing Distributes Oil Along Shaft. Used in Engines.

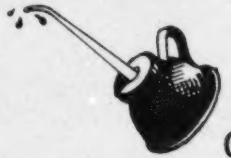


Methods of Bearing Lubrication



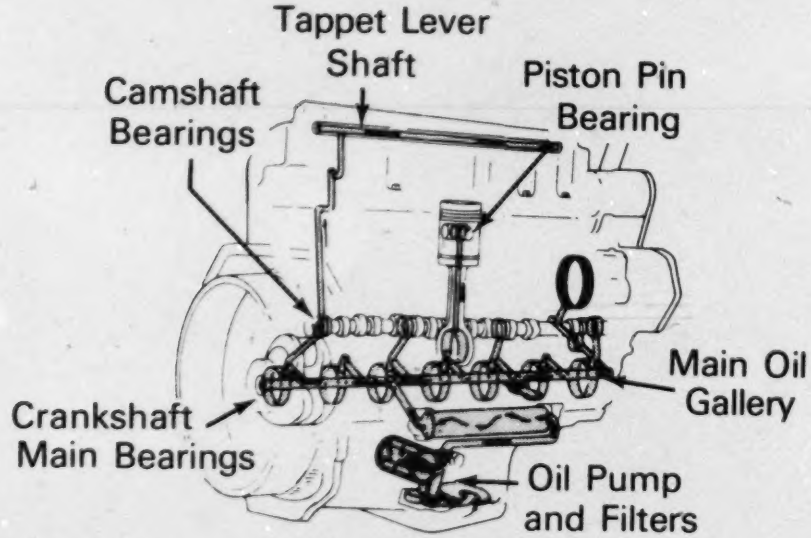
Grease Gun

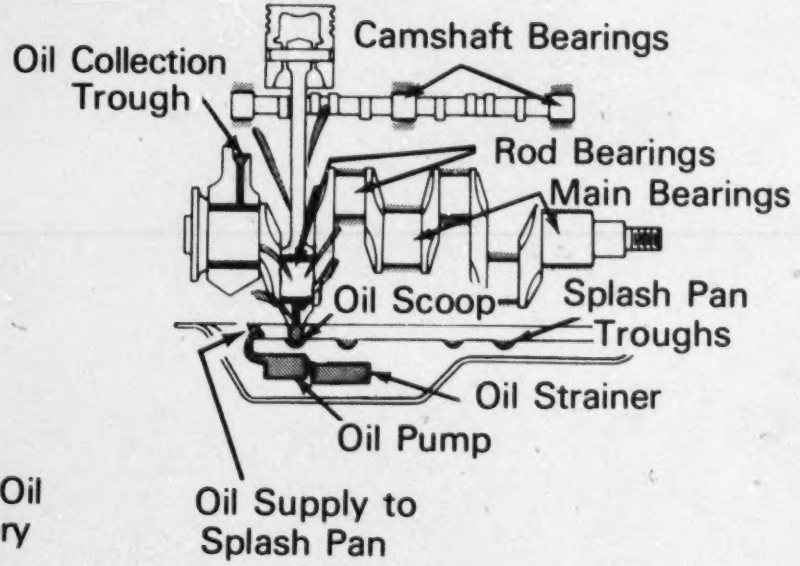
Two Types of Hand Lubrication



Oil Can

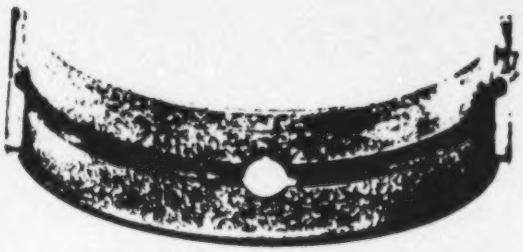
Pressure-Feed Oil System in a Typical Engine



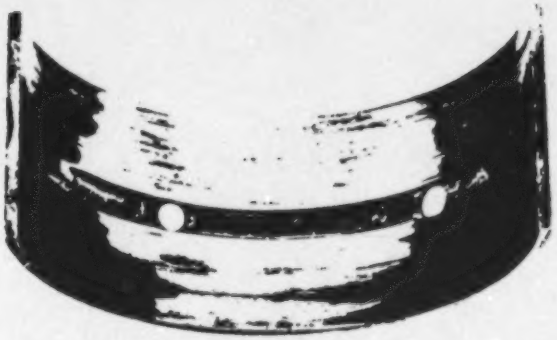


Circulating Splash System

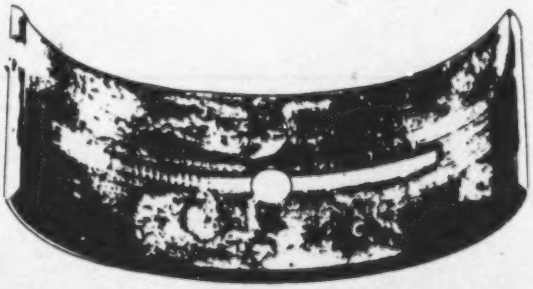
Causes of Bearing Failure



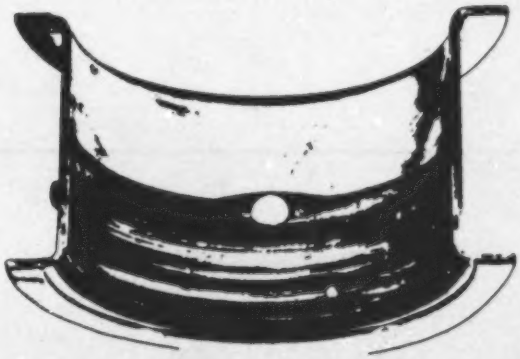
Damage From Dirt
Embedded In Bearing



Oil Starvation Caused This Damage

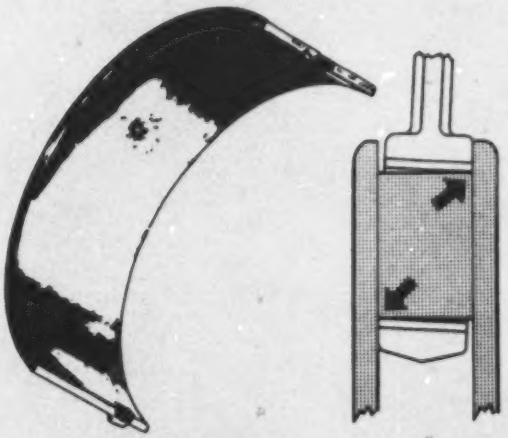


Bearing Fatigue Caused By
Overloading and Heat



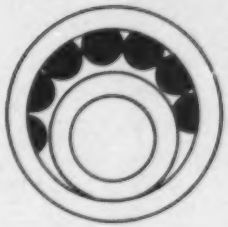
Wear On One Edge of Bearing
Caused by Tapered Journals

Corrosion From Acid
Formation In Oil



Excessive Wear Caused
by a Bent Connecting Rod

Types of Ball Bearing Races



Conrad Bearing

Inner Race In Eccentric Position For Loading. Good For Both Radial And Thrust Loads.

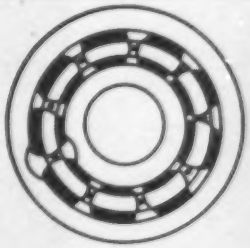
Split Race Bearing

Inner Race Is Center-Cut. Good For Thrust Loads Only.

Angular Contact Bearing

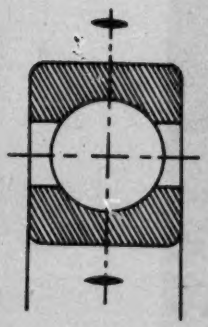
One Shoulder Of Outer Race Removed. Good For Thrust Loads - One Direction

Full Type Bearing

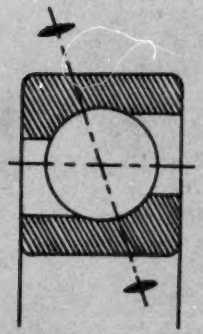


Has A Loading Slot. Holds More Balls, Only For Radial Loads.

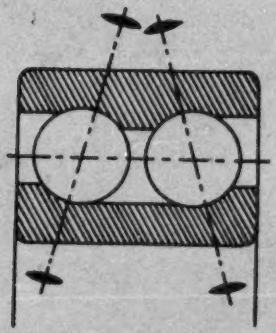
Ball Bearing Designs



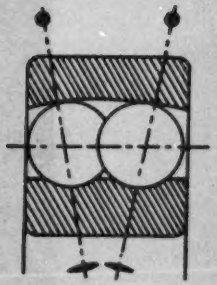
Single Row
Radial



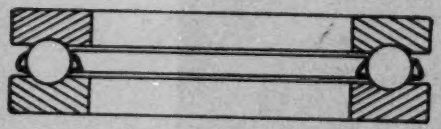
Single Row
Radial-Thrust



Double Row
Radial-Thrust

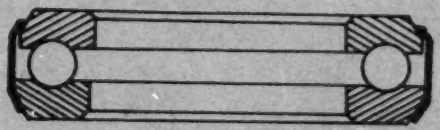


Double Row
Self-Aligning
Radial

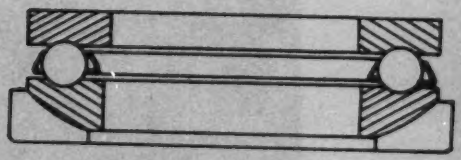


Open Face Ball
Thrust
(Separable)

Thrust-Load Ball
Bearings

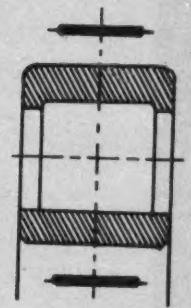


Ball Thrust
Banded Or Shielded

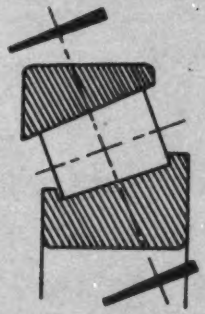


Self-Aligning Ball
Thrust
(Separable)

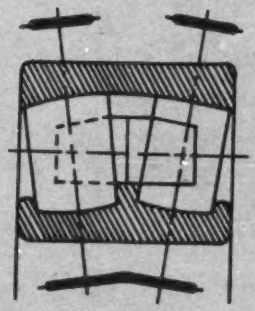
Basic Types Of Roller And Needle Bearings



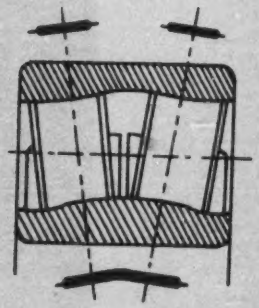
Radial Load, Straight Roller



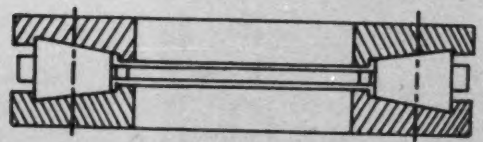
Radial-Thrust, Tapered Roller



Self-Aligning, Radial-Thrust Spherical Rollers

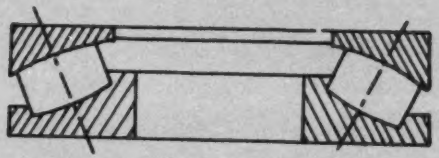


Self-Aligning, Radial-Thrust Concave Rollers

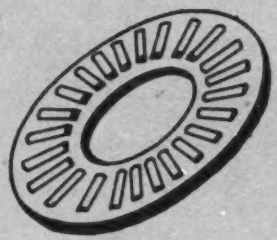


Tapered

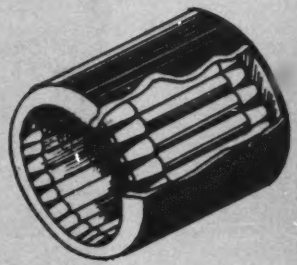
Spherical Self-Aligning



Thrust-Load Roller Bearings

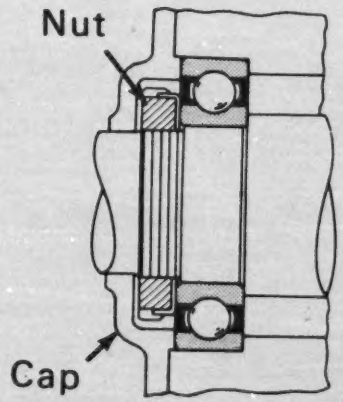


Thrust Load Bearing

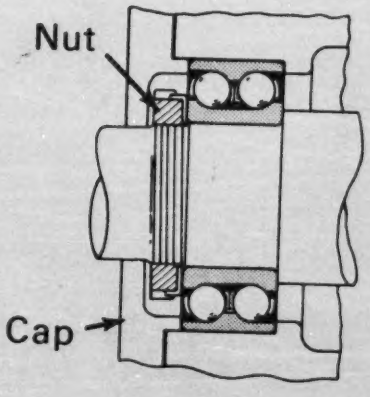


Radial Load Bearing

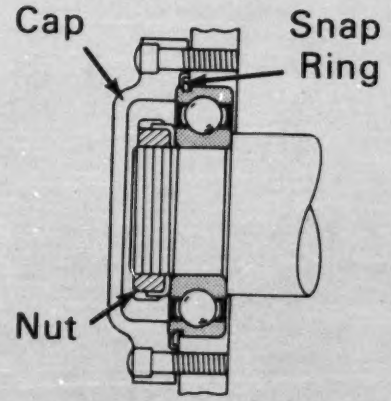
Typical Ball Bearing Mountings



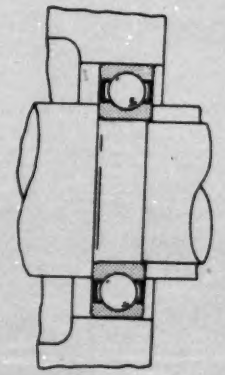
Single Row
Radial



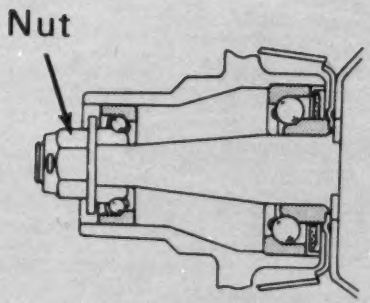
Double Row
Radial-Thrust



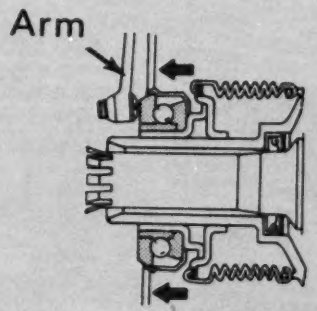
Single Row
Snap Ring



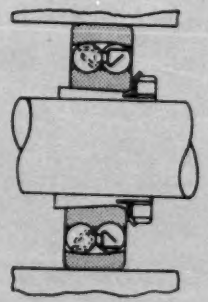
Single Row
"Floated"



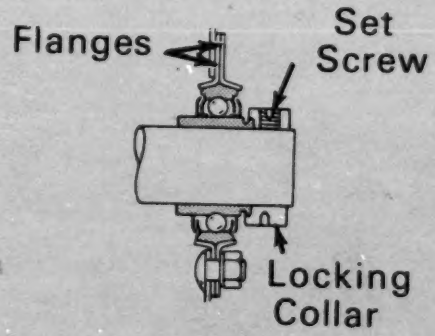
Radial-Thrust



Thrust

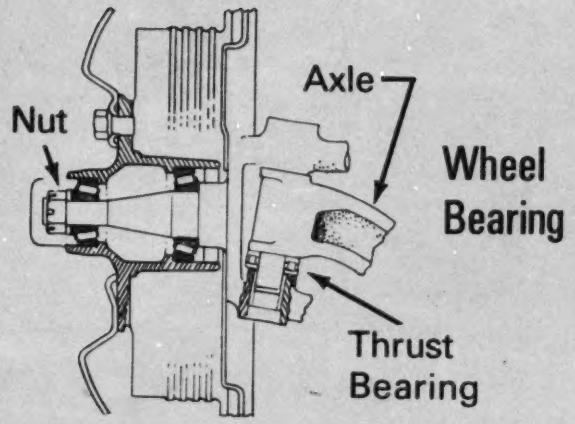


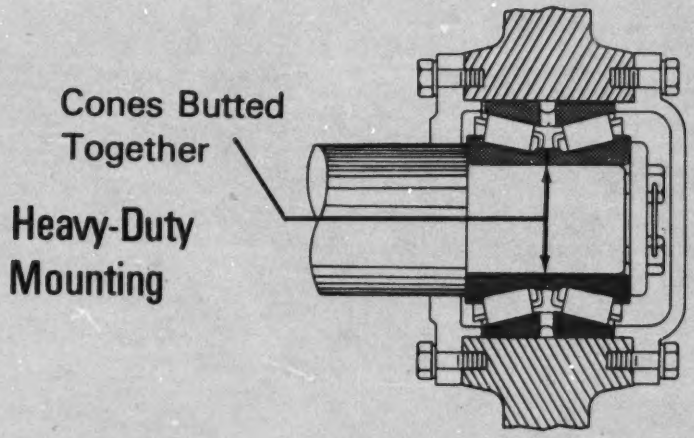
Internally
Self-Aligning

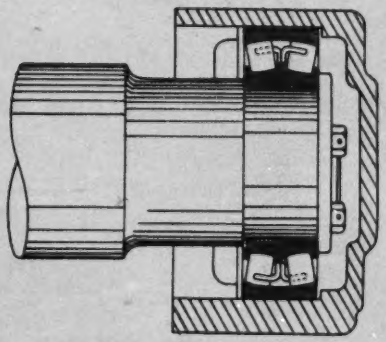


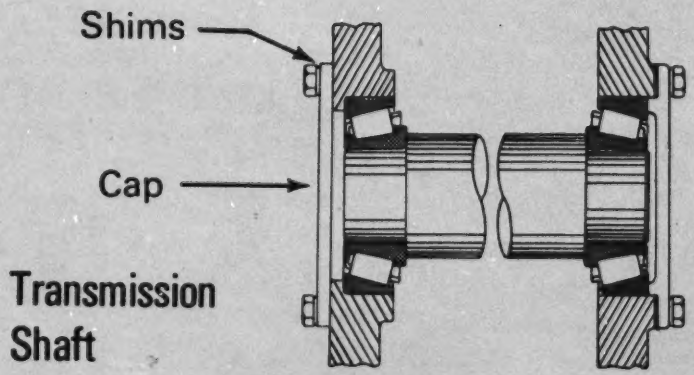
Externally
Self-Aligning

Typical Roller Bearing Mountings

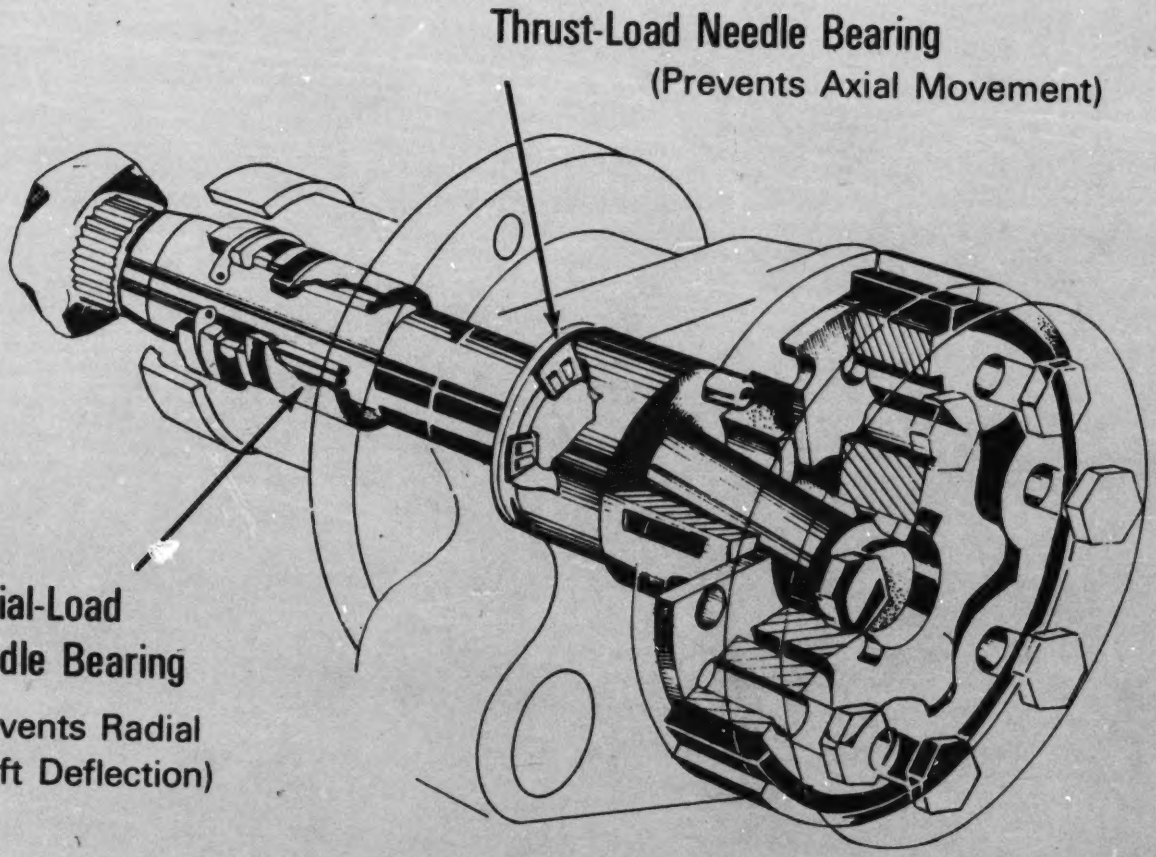








Typical Needle Bearing Mountings



BEARINGS
UNIT V

JOB SHEET #1--REMOVE AND INSTALL A PLAIN BEARING

I. Tools and materials

A. Bearing driver and adapter

B. Pilot and reamer

C. Torque wrench

D. Feeler gauge

E. Basic hand tool set

F. Shop towels

G. Safety glasses

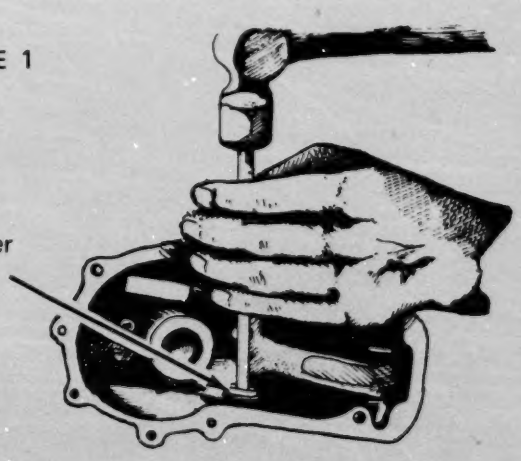
II. Procedure

A. Replace one piece bearing

1. Drive old bearing out with driver and adapter (Figure 1)

(NOTE: Be careful not to damage the bore.)

FIGURE 1



2. Clean bore and remove any burrs

JOB SHEET #1

3. Drive the bushing straight into the bore (Figure 1)

(NOTE: When possible use a press to assure accuracy. See Figure 2.)

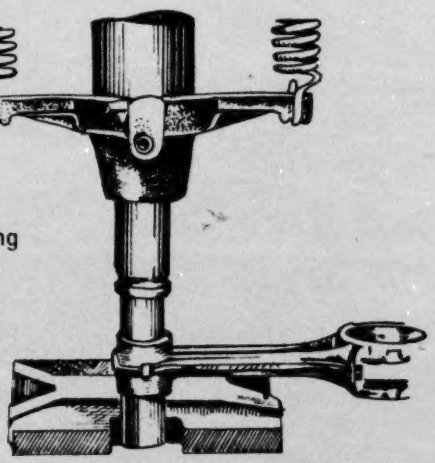


FIGURE 2

Installation Of Bearing With A Press

4. Use a pilot and reamer to size the bearing bore, if necessary (Figure 3)

(NOTE: Never turn a reamer backwards.)

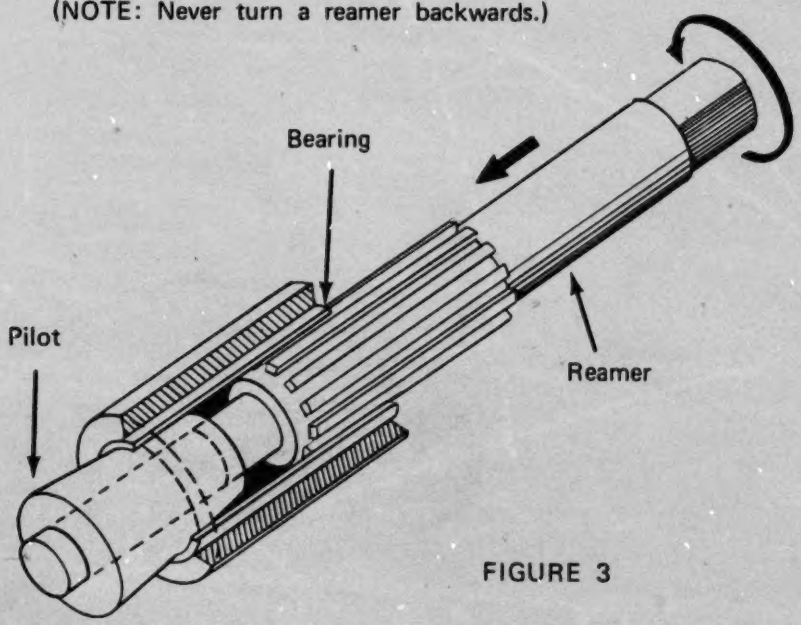


FIGURE 3

JOB SHEET #1

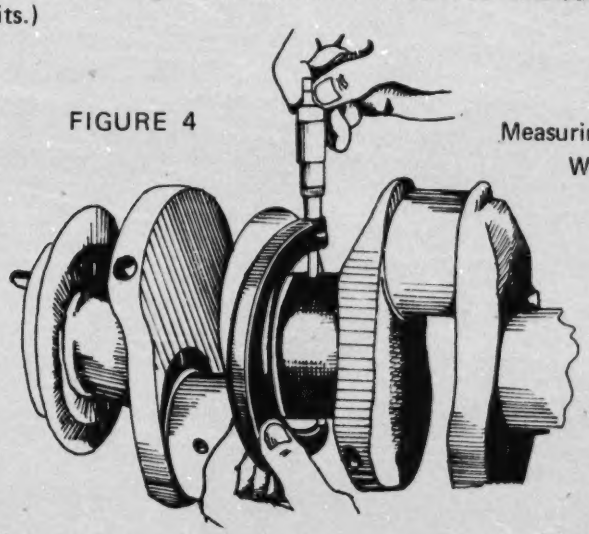
B. Replace split bearings

1. Measure several places around shaft with micrometer to determine amount of wear (Figure 4)

(NOTE: See engine manufacturer's technical manual for wear limits.)

FIGURE 4

Measuring Shaft Wear

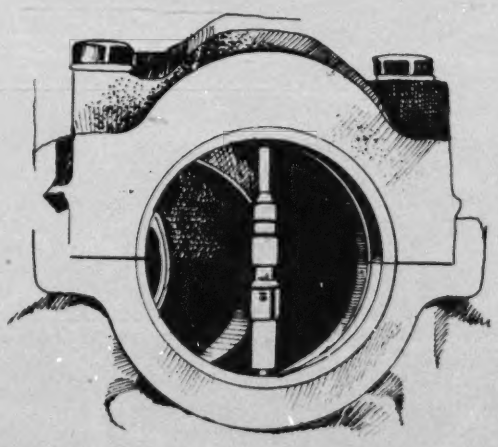


2. Install bearings and tighten to specified torque

3. Use an inside micrometer to measure the inside diameter of bearing (Figure 5)

FIGURE 5

Measuring Bearing Clearance



4. Compare the reading with the outside diameter of the shaft

JOB SHEET #1

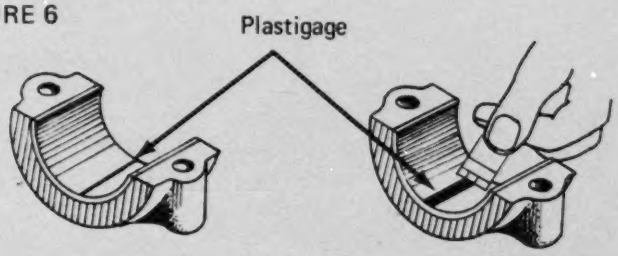
5. Determine the clearance by subtracting the shaft diameter from the bearing inside diameter

(NOTE: Refer to engine manufacturer's specifications to determine the correct clearance.)

6. Another method of measuring bearing clearance is by using a plastigage (Figure 6)

(NOTE: This is a plastic thread which "crushes" to the exact clearance when the bearing cap is fully tightened. While this method will give the bearing clearance, it will not tell you whether the wear is on the bearing or on the shaft. Crankshaft must be supported when checking main bearing clearance.)

FIGURE 6



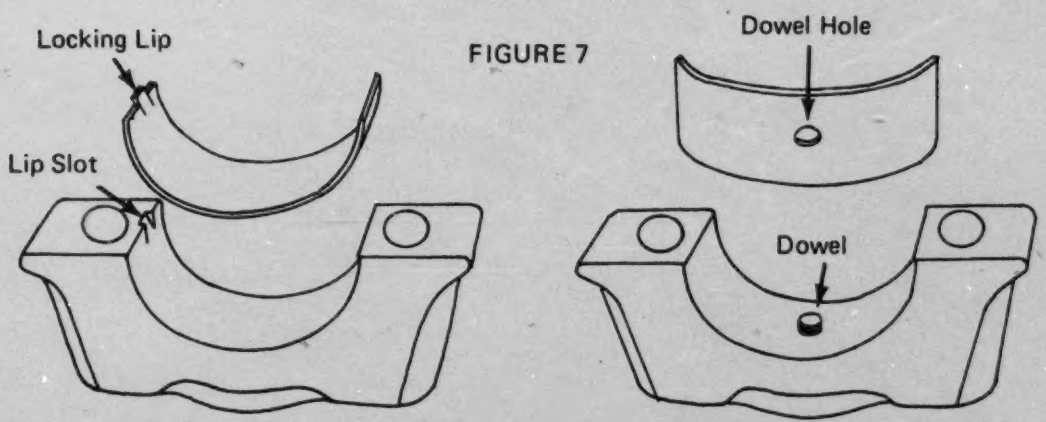
1. Plastigage In Place Before Bearing Cap Is Torqued

2. Plastigage After Bearing Cap Is Removed

7. Install undersize bearings if too much wear has occurred

(NOTE: When installing the bearing, be careful that it does not cover any oil holes and that the locking devices are in correct relationship. See Figure 7.)

FIGURE 7

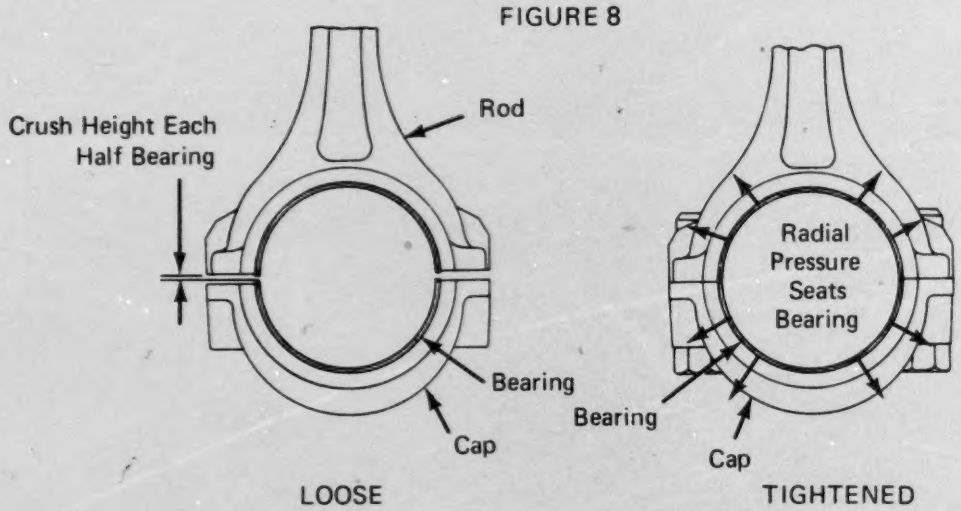


JOB SHEET #1

8. Determine the correct amount of bearing "crush"

a. Force the insert to seat solidly in bearing seat (Figure 8)

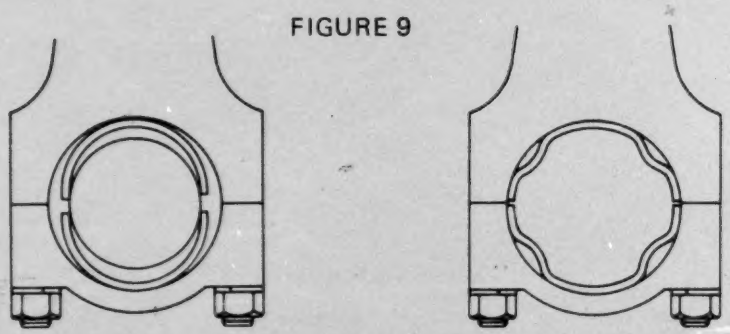
FIGURE 8



b. Insure that the bearing remains round

(NOTE: If not tightly held on the edge, it might distort as illustrated in exaggerated form. See Figure 9.)

FIGURE 9



Lack Of Crush

Edges Of Bearing Curl In Toward Shaft

Too Much Crush

Bearing Buckles When Cap Tightened

EFFECTS OF IMPROPER CRUSH

BEARINGS
UNIT V

JOB SHEET #2--REMOVE AND INSTALL AN ANTI-FRICTION BEARING

I. Tools and materials

A. Pullers

B. Press

C. Vise

D. Support blocks

E. Basic tool set

F. Shop towels

G. Safety glasses

II. Procedure

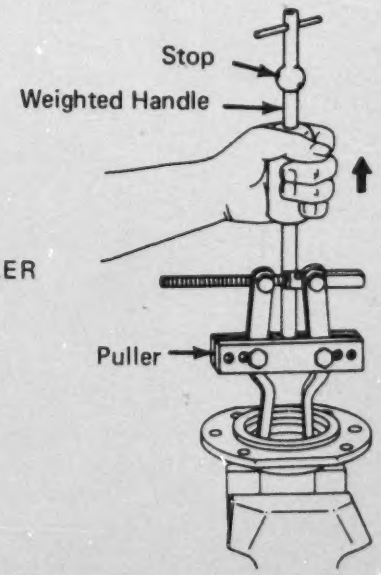
A. Remove bearing using pullers

1. Clean bearing housing and shaft

2. Study bearing mounting and determine how it can be removed using a, b, or c bearing pullers below

a. Using a slide hammer puller, slide the hammer against the stop and force bearing from housing (Figure 1)

FIGURE 1

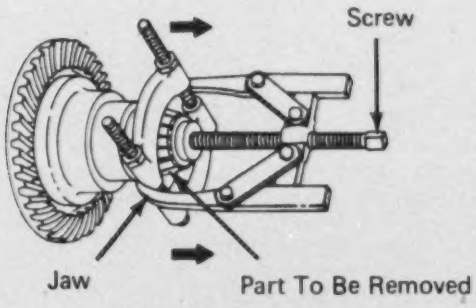


SLIDE-HAMMER
INTERNAL PULLER

JOB SHEET #2

b. Using a screw type puller, pull bearing from the shaft by force of screw turning (Figure 2)

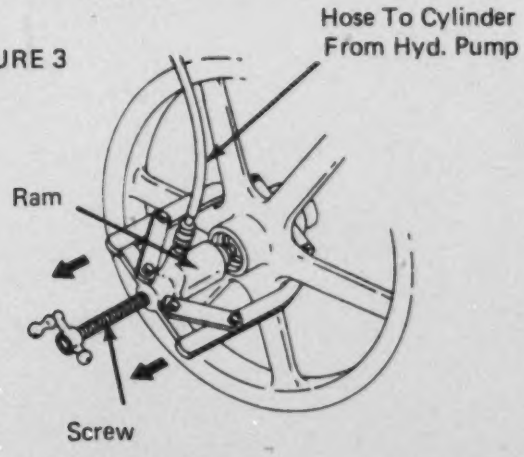
FIGURE 2



EXTERNAL SCREW-TYPE PULLER

c. Using a hydraulic powered puller, pull bearing from shaft by force (Figure 3)

FIGURE 3



HYDRAULICALLY-POWERED PULLER

3. Make the correct puller application using a, b, or c below

(NOTE: Pullers may be for either internal or external applications, depending on the need. Some pullers can be used for both jobs because they have reversible jaws with both external and internal ends.)

JOB SHEET #2

a. Make puller application using an internal type with push-puller (Figure 4)

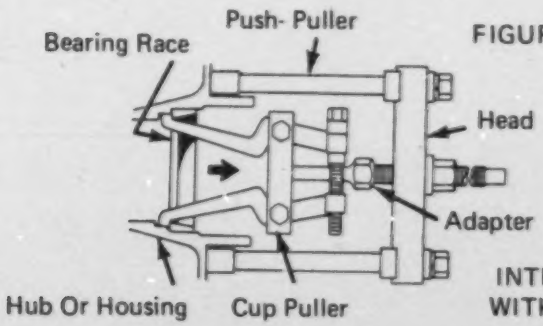


FIGURE 4

INTERNAL PULLER WITH PUSH-PULLER

(NOTE: The push-puller may also be used for installation. The legs of the push-puller support the head while the screw is turned, pulling the bearing cup from the housing.)

b. Make puller application using a knife-edge puller plate with push puller (Figure 5)

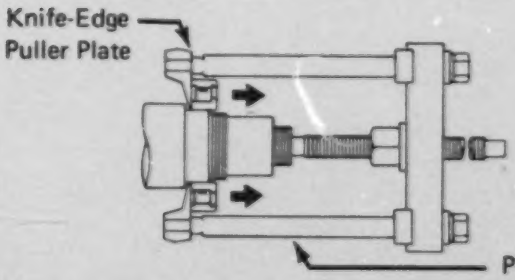


FIGURE 5

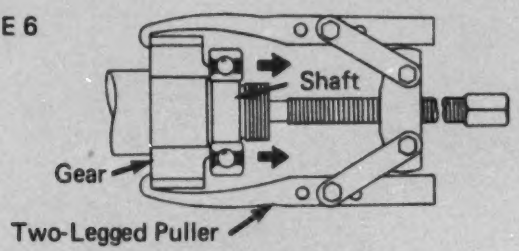
KNIFE-EDGE PULLER PLATE WITH PUSH-PULLER

(NOTE: A knife-edge puller plate is available to remove bearings where other pullers would damage the bearing. This plate is shown (Figure 5) removing a bearing from a shouldered shaft. If the regular external-type puller were used to remove this bearing, the force exerted on the outer race would damage the bearing. Notice that the knife-edge plate is used with a push-puller; the external screw type puller can also be used with the knife-edge plate.)

JOB SHEET #2

c. Make puller application using an external screw type puller (Figure 6)

FIGURE 6



EXTERNAL SCREW TYPE PULLER

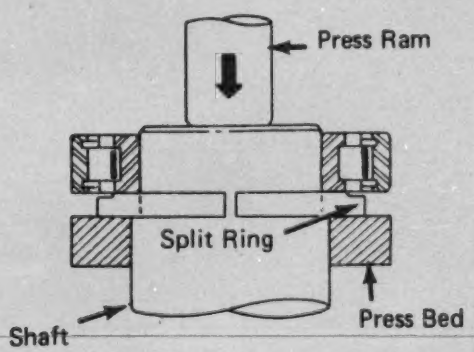
(NOTE: The external screw type puller can be used to remove bearings provided there is some solid object which allows the jaws of the puller to force the bearing off.)

4. Force the bearing from the shaft

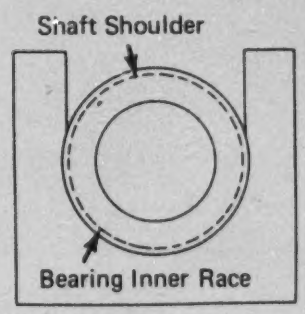
B. Remove bearing using a press (Figure 7)

1. Support inner race with split rings or U-plates as available (Figure 7)

FIGURE 7



SPLIT RING SUPPORT



U-PLATE SUPPORT

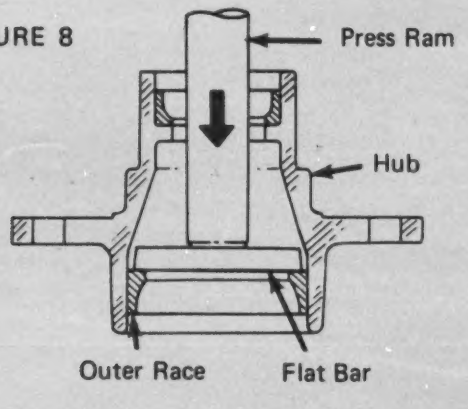
2. Press bearing from shaft

JOB SHEET #2

3. Press bearing cup from housing using a flat bar which transmits ram pressure (Figure 8)

(NOTE: Housing must be open from opposite side.)

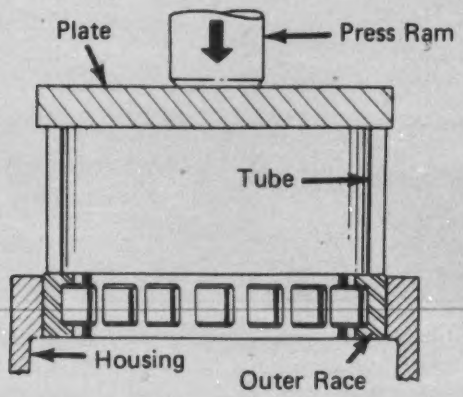
FIGURE 8



BEARING CUP REMOVAL

4. Press outer race from housing using a tube slightly smaller than the outer race (Figure 9)

FIGURE 9



JOB SHEET #2

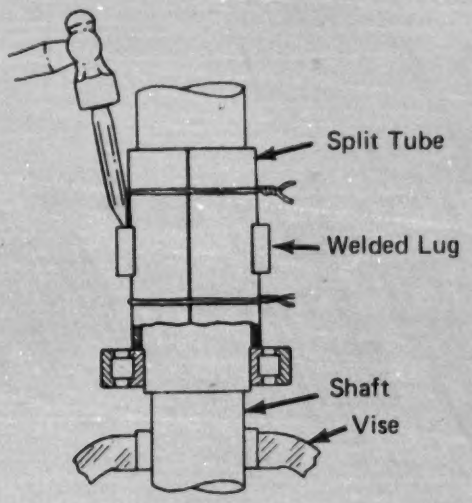
C. Remove bearing with a hammer and driver using either method below

1. Method #1

a. Place tube over shaft to drive bearing from the shaft (Figure 10)

(NOTE: If shaft has obstructions, tube may be split and tied.)

FIGURE 10



b. Strike the welded lug with hammer and punch

2. Method #2

a. Use support blocks, split rings, or a U-plate to support inner race of the bearing (Figure 11)

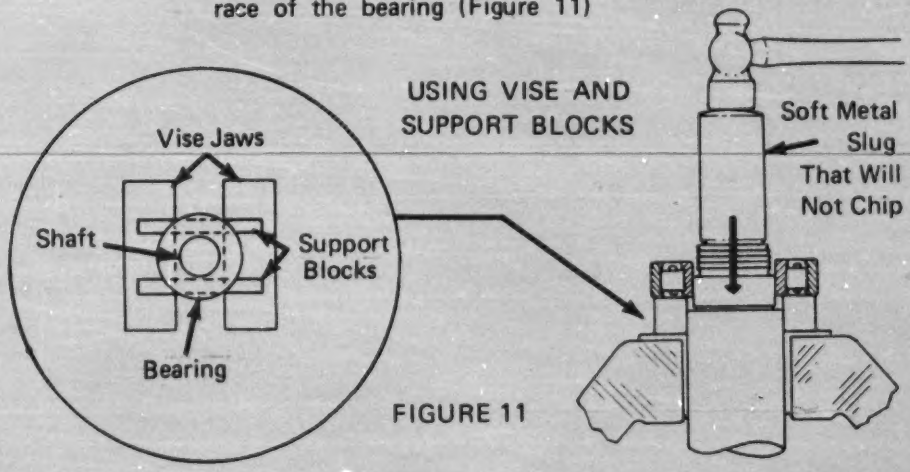


FIGURE 11

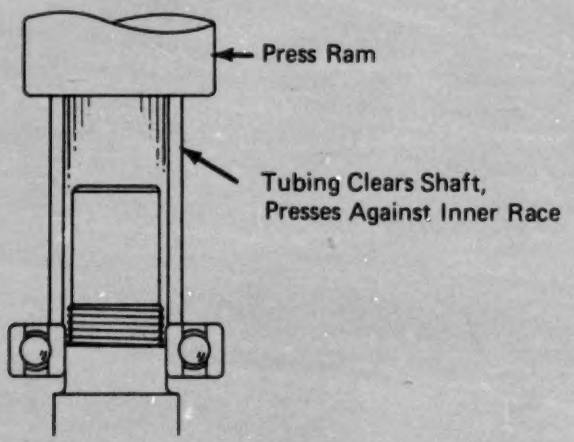
JOB SHEET #2

b. Drive the shaft from the bearing with a soft plug or driver

D. Install bearings using appropriate method below

1. Press inner face on shaft by using press method (Figure 12)

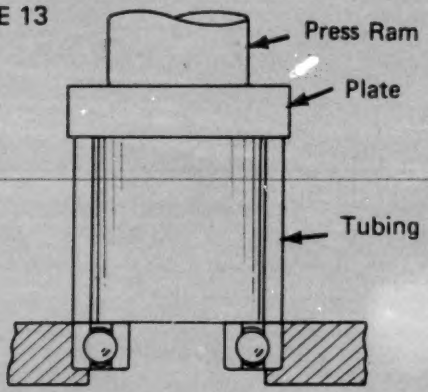
FIGURE 12



(NOTE: No pressure is exerted on outer race.)

2. Press outer race in housing by using press method (Figure 13)

FIGURE 13

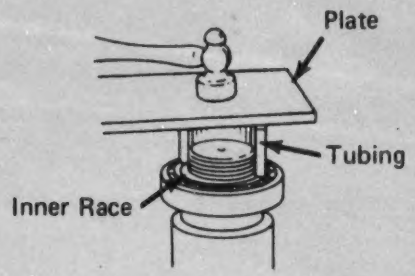


(NOTE: No pressure is exerted on inner race.)

JOB SHEET #2

3. Drive inner race on shaft with hammer (Figure 14)

FIGURE 14

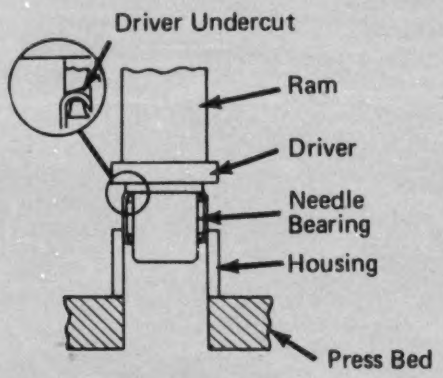


DRIVING INNER RACE ON SHAFT

(NOTE: No pressure is exerted on outer race.)

4. Press needle bearing into housing with press (Figure 15)

FIGURE 15



(NOTE: Use special undercut driver to transmit driving force to outer shell, preventing bearing shell from buckling.)

BEARINGS
UNIT V

JOB SHEET #3--CHECK PRELOAD BEARING SETTING, SPRING SCALE METHOD

I. Tools and materials

A. Safety glasses

B. Appropriate service manual

C. Spring scale

D. String or cord

E. Basic hand tool set

F. Torque wrench

II. Procedure

A. Torque bearing adjusting device to manufacturer's specification

B. Lubricate bearings, if necessary

C. Attach string to gear and wind around the outside diameter

D. Attach spring scale to string (Figure 1)

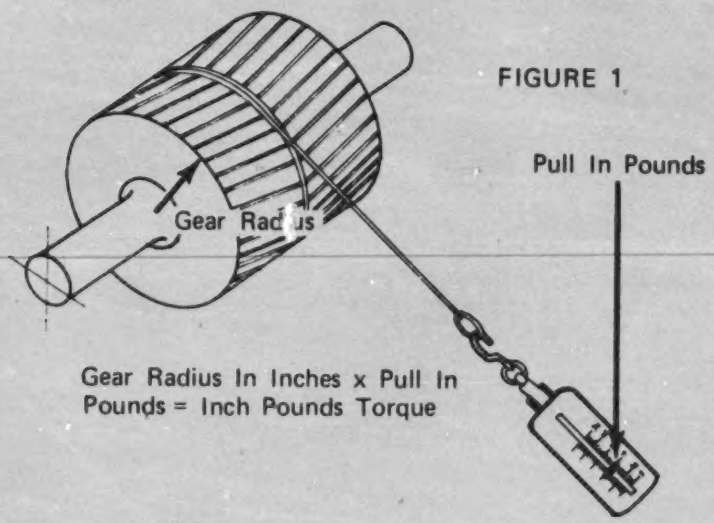


FIGURE 1

E. Pull until gear is rotated slowly (Figure 1)

JOB SHEET #3

F. Read the pounds pull necessary to keep gear turning

G. Calculate the rolling torque by multiplying the radius of the gear in inches by the pounds pull on the spring scale (Figure 1)

(NOTE: Compare calculated rolling torque to manufacturer's specifications.)

H. Tighten or loosen the adjusting device to obtain manufacturer's preload bearing setting

BEARINGS
UNIT V

NAME _____

TEST

1. Match the terms on the right to the correct definitions.

_____a. Resistance to motion between two bodies in contact

_____b. Force is directed sideways or perpendicular to the shaft

_____c. Force is directed endways or horizontal to shaft

_____d. Two hardened steel rings

_____e. Plastic thread which "crushes" to the exact clearance when measuring bearing clearance

_____f. Alloy of lead, tin, antimony, and other metals

_____g. Supporting surface for a wheel or shaft that provides a sliding contact between the mating surfaces

_____h. Supporting surface for a wheel or shaft that provides a rolling contact between mating surfaces

_____i. Each half of the bearing extends one or two thousandths of an inch beyond the bearing seat bore

_____j. Adjustment of anti-friction bearing after being secured in the mounting

1. Axial load
2. Radial load
3. Friction
4. Plastigage
5. Plain bearing
6. Anti-friction bearing
7. Babbit
8. Bearing crush
9. Races
10. Preloading

2. List four functions of bearings.

a.

b.

c.

d.

3. Name two basic types of bearings.

a.

b.

4. Discuss load forces on bearings.

5. Match the types of bearings on the right to their advantages and disadvantages.

_____a. Advantages
1) Require little space
2) Low in cost
3) Quiet operation
4) Rigid construction

_____b. Advantages
1) Low friction operation
2) Can be packed to reduce frequency of lubrication
3) More versatile, many designs

_____c. Disadvantages
1) High friction operation
2) Require more frequent lubrication because they cannot be packed

_____d. Disadvantages
1) Require more space
2) Noisier operation
3) Higher cost
4) Less rigidity

1. Plain bearings (bushings)

2. Anti-friction bearings

6. Match the illustrations of plain bearings to the correct names.

_____a. Solid bearing or sleeve

_____b. Split bearing, rolled type

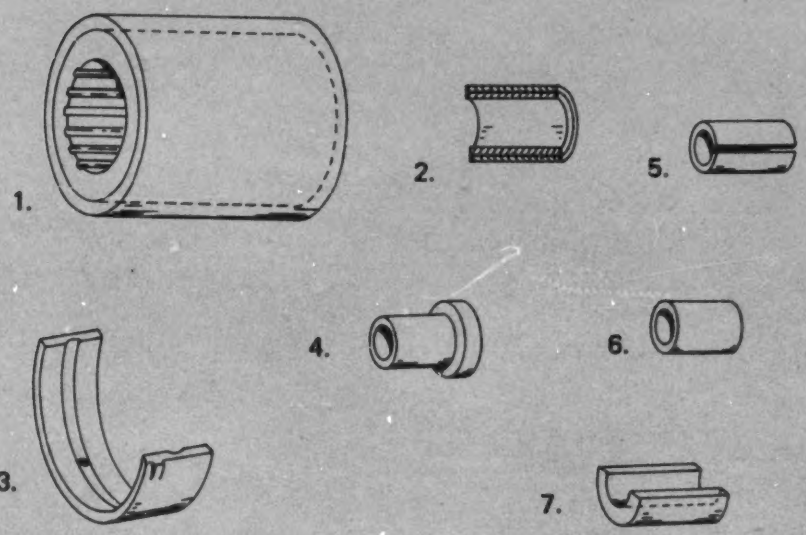
_____c. Thrust bearing

_____d. Split bearing with steel back lined with bronze or babbit

_____e. Split type constructed of wood, plastic, or rubber

_____f. Split bearing used for engine crankshaft

_____g. Solid bearing with fluted rubber structure



7. List six materials from which bearings may be constructed.

a.

b.

c.

d.

e.

f.

8. List three factors influencing the distribution of lubricant to the bearings.

a.

b.

c.

9. Name four common methods of lubricating bearings.

a.

b.

c.

d.

10. List five causes of bearing failure in plain bearings.

a.

b.

c.

d.

e.

11. List four reasons for bearing crush.

a.

b.

c.

d.

12. Name three types of anti-friction bearings.

a.

b.

c.

13. List three conditions that determine the load carrying capacity of anti-friction bearings.

a.

b.

c.

14. Name four types of ball bearing races.

a.

b.

c.

d.

15. List four designs of ball bearings.

a.

b.

c.

d.

16. List five types of roller bearings.

a.

b.

c.

d.

e.

17. Name two types of needle bearings.

a.

b.

18. Discuss mountings for anti-friction bearings.

19. Select bearing maintenance tips by placing an "X" in the appropriate blanks.

_____a. Work with clean, approved tools, in clean surroundings

_____b. Use clean solvents and flushing oils

_____c. Install new bearings as they come from the package, without washing, if they are received in a sealed container

_____d. Use wooden mallets or work on a soft wood bench

_____e. Lay bearings out on a clean surface

_____f. Handle bearings with dirty or moist hands

_____g. Keep bearings wrapped in oil-proof paper when not in use

_____h. Wipe bearings, if necessary, only with clean, lint-free rags

_____i. Expose bearings to moisture and dirt

_____j. Use the same container for both cleaning and final rinse of used bearings

_____k. Keep lubricants clean when applying them, and cover the containers when not in use

20. Demonstrate the ability to:

a. Remove and install a plain bearing.

b. Remove and install an anti-friction bearing.

c. Check preload bearing setting, spring scale method.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

BEARINGS
UNIT V

ANSWERS TO TEST

1. a. 3
   b. 2
   c. 1
   d. 9
   e. 4
   f. 7
   g. 5
   h. 6
   i. 8
   j. 10

2. a. Support the moving part
   b. Reduce friction
   c. Reduce wear
   d. Provide a replaceable wear surface

3. a. Plain bearings
   b. Anti-friction bearings

4. Discussion should include:
   a. Axial load forces are those forces directed endways
   b. Radial load forces are those forces directed sideways or perpendicular to the shaft

5. a. 1
   b. 2
   c. 1
   d. 2

6. a. 6
   b. 5
   c. 4
   d. 2
   e. 7
   f. 3
   g. 1

7. Any six of the following:
   a. Wood
   b. Cast iron
   c. Soft steel
   d. Hard steel
   e. Copper, brass, and bronze
   f. Copper, lead
   g. Babbit
   h. Aluminum
   i. Plastic
   j. Rubber
8. a. Oil grooves
   b. Bearing clearance
   c. Bearing surface compatibility
9. Any four of the following:
   a. Oil can
   b. Grease gun
   c. Central grease system
   d. Oil bath splash
   e. Pressure feed system
10. Any five of the following:
   a. Dirt
   b. Lack of lubrication
   c. Improper assembly
   d. Misalignment
   e. Overloading
   f. Corrosion

11. a. Greater heat dissipation
    b. Insert is forced to seat solidly
    c. Insures that the bearings remain round
    d. Avoids any possible movement of the bearing in the seat
12. a. Ball
    b. Roller
    c. Needle
13. a. Size of bearing
    b. Number of rolling elements
    c. Type of race
14. a. Conrad
    b. Full type
    c. Split race
    d. Angular contact
15. a. Radial load
    b. Radial and thrust load
    c. Self-aligning, radial load
    d. Thrust load
16. a. Radial load, straight roller
    b. Radial and thrust load, tapered roller
    c. Self-aligning, radial and thrust load, spherical roller
    d. Self-aligning, radial and thrust load, concave roller
    e. Thrust load
17. a. Radial load
    b. Thrust load

18. Discussion should include:

    a. Shape must not be distorted

    b. Rolling elements must not be bound

    c. Inner and outer races must be aligned

    d. Axis of each bearing must be aligned with the other

    e. Usually mounted with one race a press fit and the other a push fit

    f. Seals are used to retain lubricant and exclude dirt

19. a, b, c, e, g, h, k

20. Performance skills evaluated to the satisfaction of the instructor

SEALS
UNIT VI

UNIT OBJECTIVE

After completion of this unit, the student should be able to list three uses of seals and name places where dynamic and static seals are used. The student should also be able to match the names of the dynamic seals to their functions and install a radial lip type seal. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with seals to the correct definitions.
2. List three uses of seals.
3. Name two basic types of seals and their uses.
4. Name three places where dynamic seals are used.
5. Name three places where static seals are used.
6. Match the names of the dynamic seals to their functions.
7. List four types of static seals.
8. Name three catagories of sealants.
9. Demonstrate the ability to install a radial lip type seal.

SEALS
UNIT VI

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined in the job sheet.

G. Display several types of dynamic and static seals including O-rings, gaskets, and diaphragms.

H. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete job sheet.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Basic Types of Seals
2. TM 2--Dynamic Seals
3. TM 3--Dynamic Seals (Continued)

4. TM 4--Dynamic Seals (Continued)
5. TM 5--Dynamic Seals (Continued)
6. TM 6--Dynamic Seals (Continued)
7. TM 7--Dynamic Seals (Continued)
8. TM 8--Dynamic Seals (Continued)
9. TM 9--Dynamic Seals (Continued)
10. TM 10--Dynamic Seals (Continued)
11. TM 11--Dynamic Seals (Continued)
12. TM 12--Dynamic Seals (Continued)
13. TM 13--Static Seals
14. TM 14--Static Seals (Continued)
15. TM 15--Static Seals (Continued)

II. Reference--*Fundamentals of Service: Bearings and Seals.* Moline, Illinois: Deere and Company, 1974.

SEALS
UNIT VI

INFORMATION SHEET

I. Terms and definitions

- A. Dynamic--Moving; relating to force
- B. Static--Without motion; still or fixed
- C. Sealant--Similar to gaskets except applied as a liquid or paste
- D. Static seal--Device which maintains a barrier against the transfer of fluids across two mating surfaces which do not move relative to each other
- E. Gasket--Type of static seal

II. Uses of seals

- A. To keep in fluids
- B. To keep out dirt
- C. To hold pressures or vacuums

III. Basic types of seals and their uses (Transparency 1)

- A. Dynamic--To seal moving parts
- B. Static--To seal fixed parts

IV. Places where dynamic seals are used

- A. Shafts and rods
- B. Compression packings
- C. Piston rings

V. Places where static seals are used

- A. As gaskets
- B. O-rings
- C. Packings

INFORMATION SHEET

VI. Dynamic seals and their functions (Transparencies 2,3,4,5,6,7,8,9,10,11, and 12)

A. Radial lip seals--Used on systems which have moving shafts

(NOTE: Lip seals may be bonded or assembled and are classified by lip types: single lip, double lip, and dual lip.)

B. Exclusion seals--Used to prevent entry of foreign material into the moving parts of machinery

(NOTE: Exclusion seals are classified into four general groups: wipers, scrapers, axial seals, and boots.)

C. Clearance seals--Limit leakage by closely controlling the annular clearance between a rotating or reciprocating shaft and stationary bushing

(NOTE: Clearance seals are classified as labyrinth seals or bushings (rings) and some leakage is permitted.)

D. Ring seals--Depend on surface contact between the seal and the moving part and the seal and the stationary part

(NOTE: Ring seals are split-ring type for reciprocating parts and circumferential for rotary parts.)

E. Face seals--Form a running seal between flat, precision finished surfaces

(NOTE: All face seals have a rotating seal ring, stationary seal ring, spring loaded devices, and static seals.)

F. Compression packings--Create a seal when squeezed between the throat of a stuffing box and its gland

(NOTE: Three classes of packings are fabric, metallic, and plastic.)

G. Molded packings--Fluid being sealed supplies the pressure to seal the packings against the wearing surface

(NOTE: The major types are lip and squeeze. Lip type packings include flange, cup, U-cup, U-ring, and V-ring packings. Squeeze types include O-rings and related forms, plus felt.)

H. Diaphragm seals--Dividing membrane which spans the gap between a moving and stationary member

(NOTE: Diaphragms are two types, rolling and flat. The rolling are like long travel bellows.)

INFORMATION SHEET

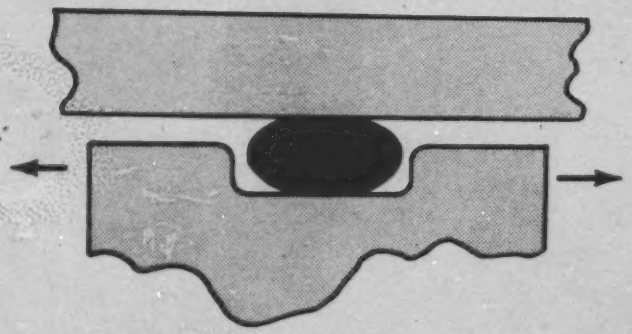
VII. Types of static seals (Transparencies 13 and 14)

- A. Nonmetallic
- B. Metallic
- C. Static O-rings (nonmetallic)
- D. Static O-rings (metallic)

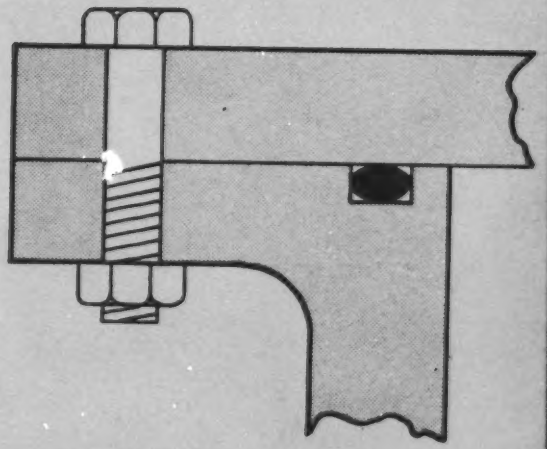
VIII. Categories of sealants (Transparency 15)

- A. Hardening types
- B. Nonhardening types
- C. Tapes

Basic Types of Seals

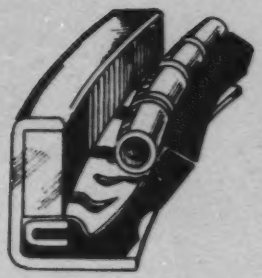


Dynamic Seal

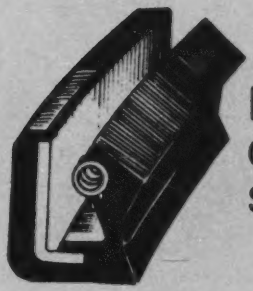


Static Seal

Dynamic Seals



Assembled Seal



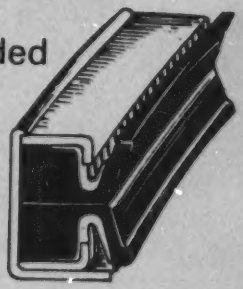
Double Lip Seal
One Lip
Spring-Loaded

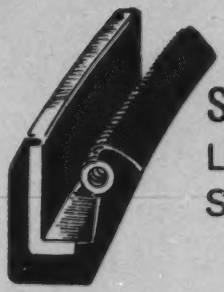
Bonded Seal

Radial Lip Seals

Single Lip Seal
Not
Spring-Loaded

Dual Lip Seal
Both Lips
Spring-Loaded

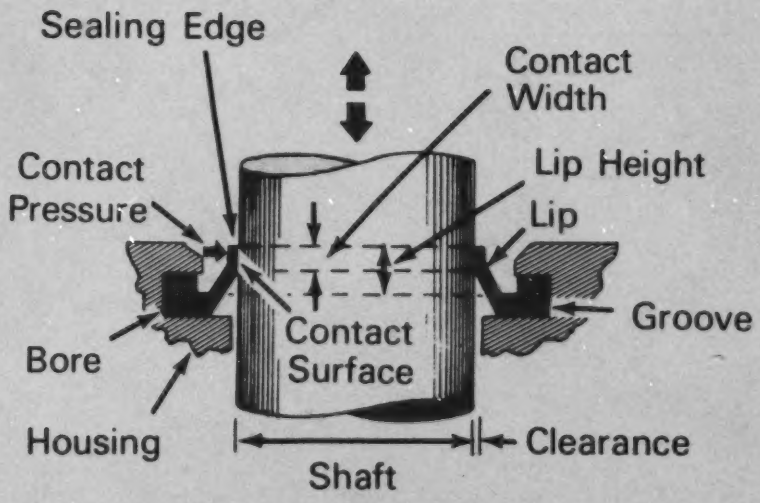




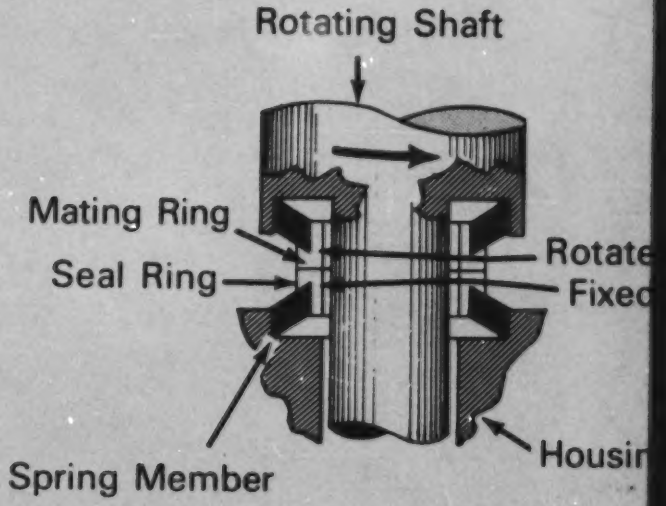
Single Lip Seal
Lip
Spring-Loaded

Dynamic Seals
(Continued)

Exclusion Seals

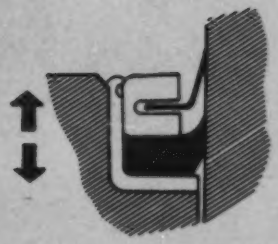


Radial Exclusion Seal

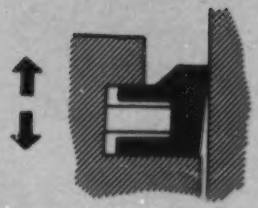


Axial Seal

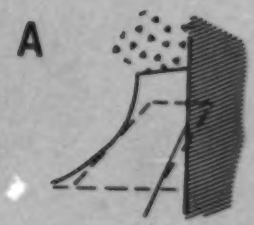
Dynamic Seals
(Continued)



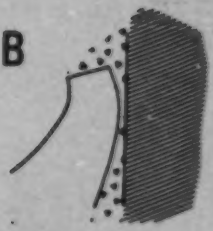
Conical Scraper



Ring Scraper



Proper Operation

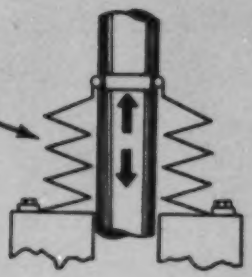


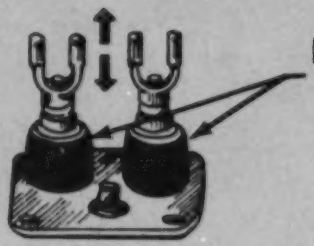
Lack Of Contact Pressure

Scrapers

Exclusion Seals

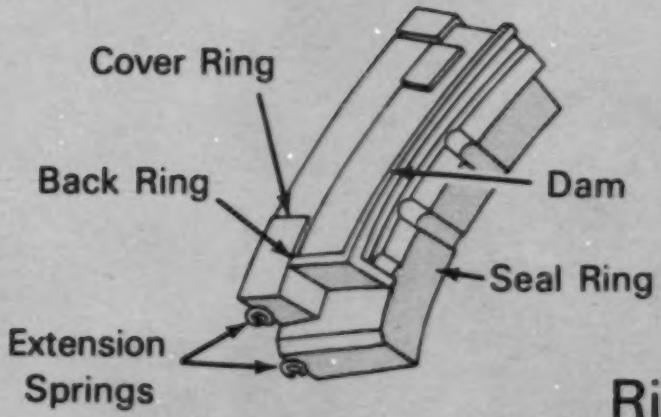
Lips Of Wiper Seals



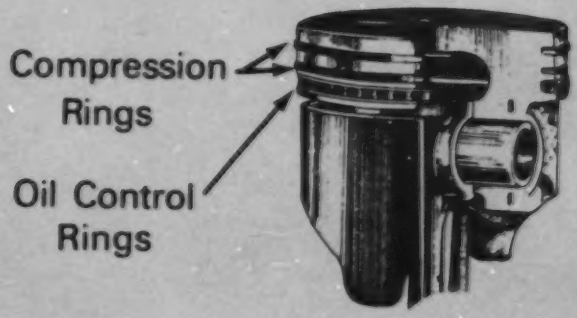


Boots Which Protect Reciprocating Shafts

Dynamic Seals
(Continued)

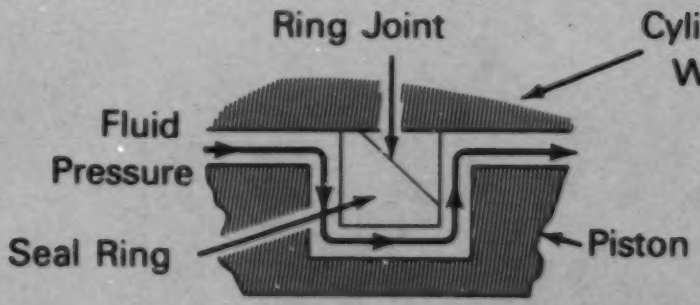


Circumferential Seal



Split-Ring Seals
On An Engine Piston

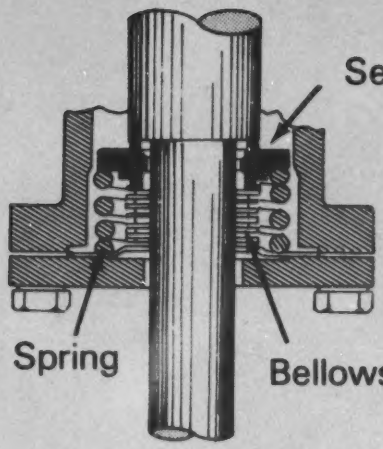
Ring Seals



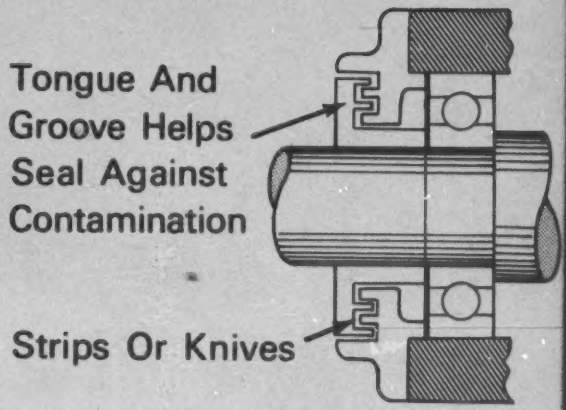
How A Split Ring Seals

Dynamic Seals

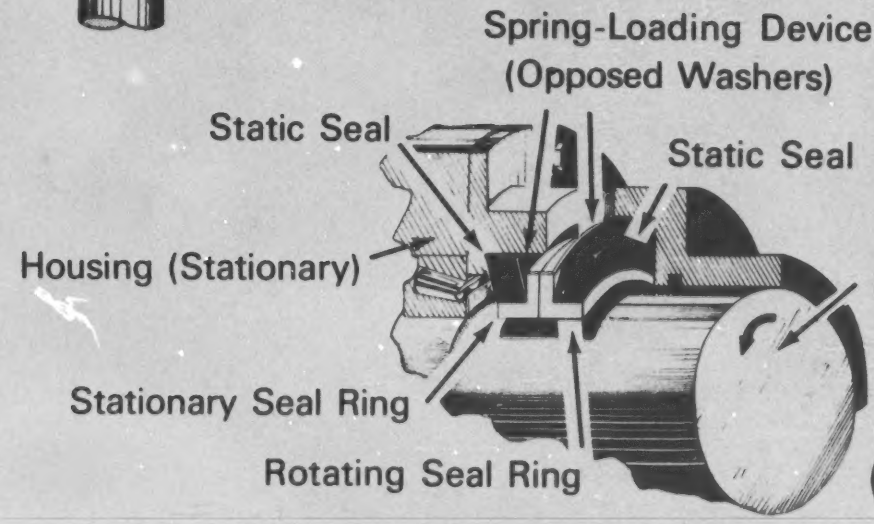
(Continued)



Metal Bellows Seal
On Shaft

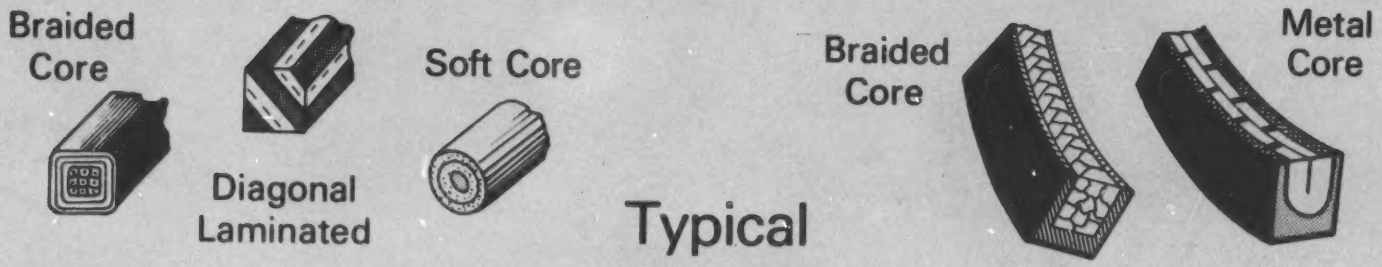


Labyrinth Seal
(Clearance Seal



Face Seal
(Axial Mechanical Seal)

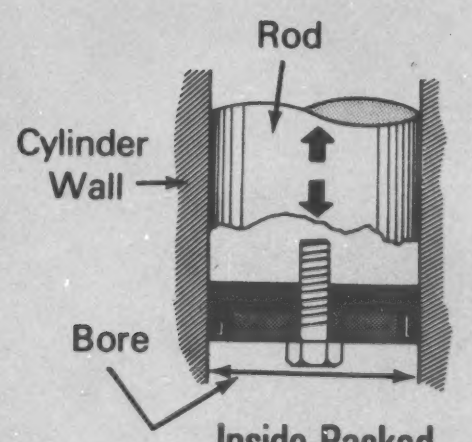
Dynamic Seals
(Continued)



Fabric Packings

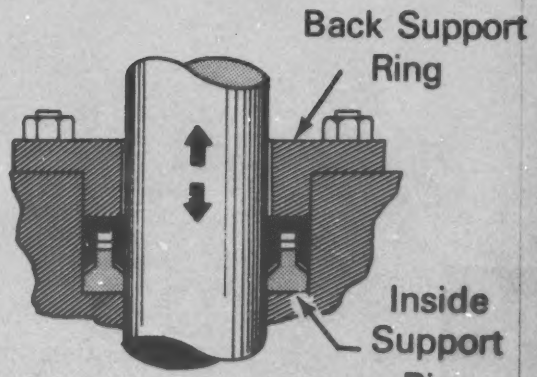
Typical Compression Packings

Metallic Packings



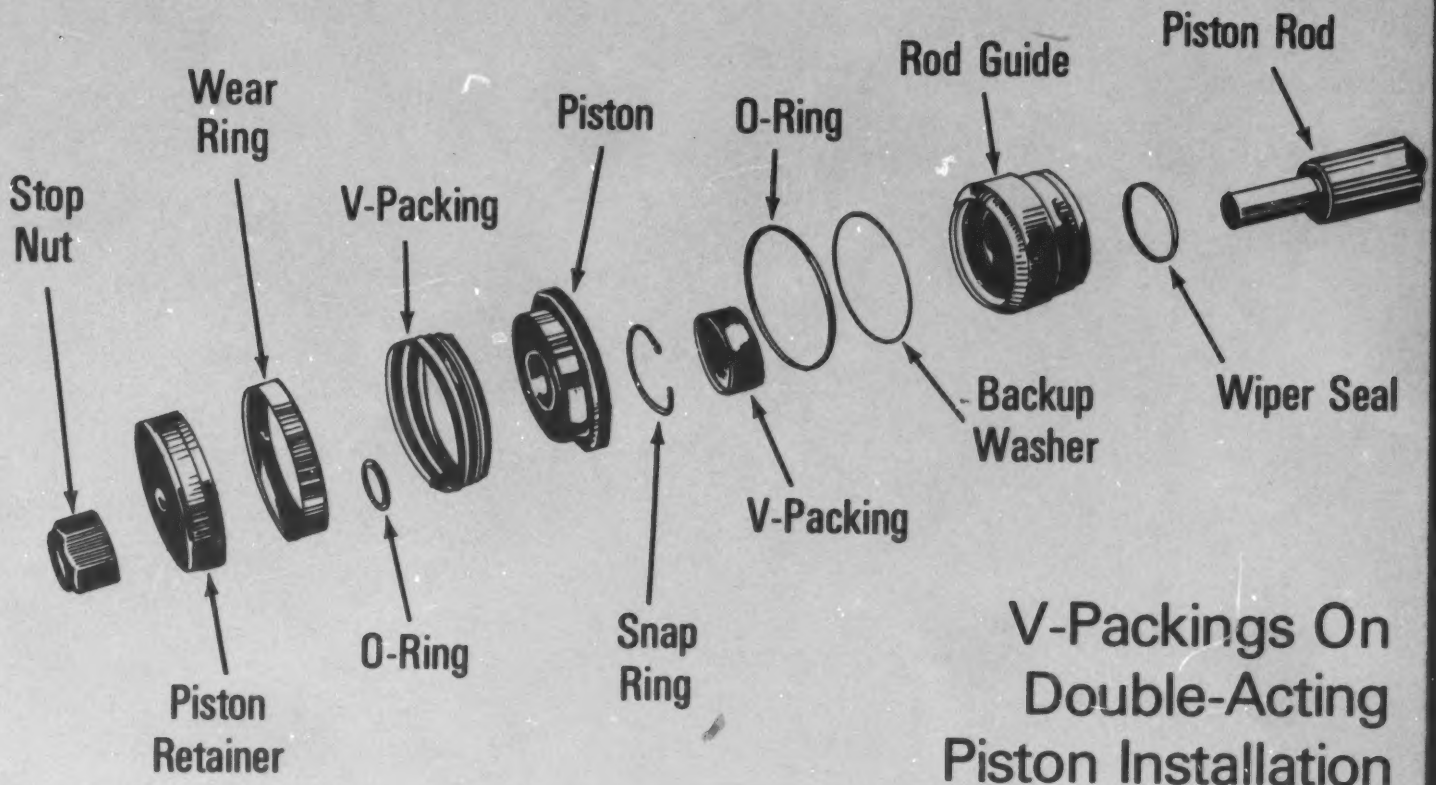
Inside-Packed

Inside And Outside-Packed Installations



Outside-Packed

Dynamic Seals
(Continued)

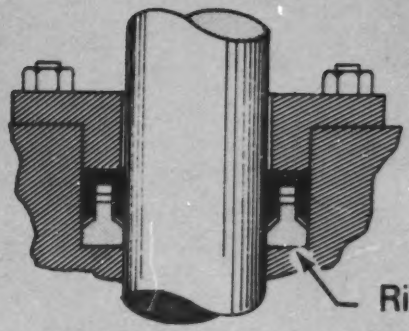


V-Packings On Double-Acting Piston Installation

Dynamic Seals

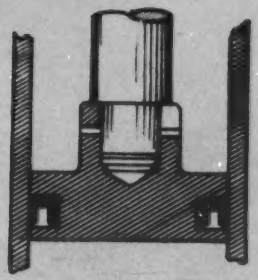
(Continued)

Typical U-Cup Packings



Leather U-Packing Supported By Metal Pedestal Ring Drilled Cross-Wise To Equalize Pressure.

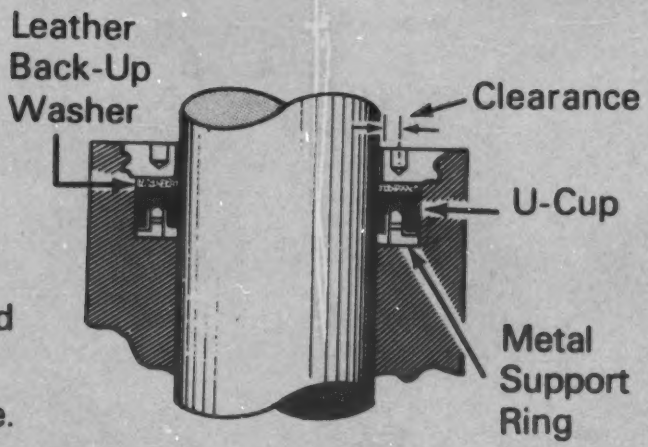
Molded Packings



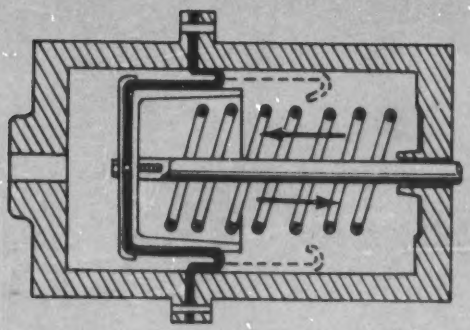
Inside-Packed Installation For A Single-Acting Piston.

U-Ring Packing (Leather Type Shown)

Outside-Packed Installation With Ring And U-Cup Supported On A Pedestal Ring Drilled Cross-Wise To Equalize Pressure.

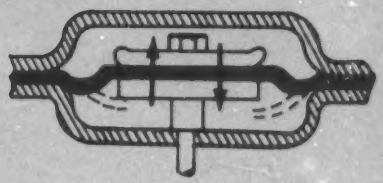


Dynamic Seals
(Continued)

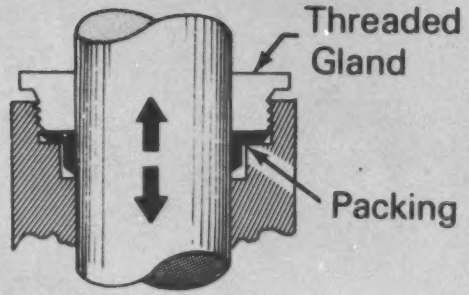


Rolling Diaphragm

Diaphragm Seals



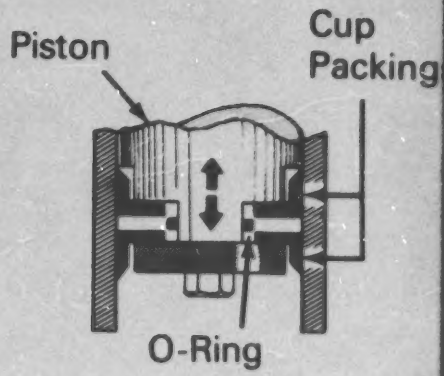
Flat Diaphragm



Flange Packings

Molded Packings

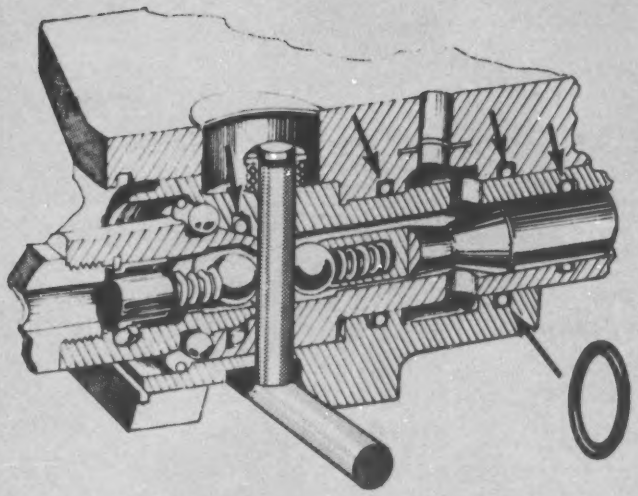
Sleeve Prevents
Transfer Of Loads
Between Cups



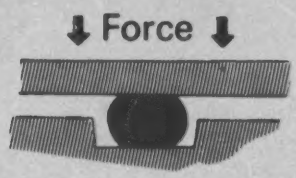
Cup Packings For
Double-Acting Unit

Dynamic Seals
(Continued)

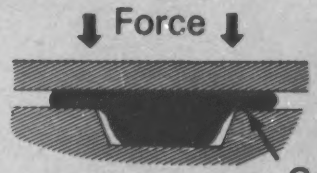
Molded Packings



Squeeze-Type Packings
(O-Rings Shown)

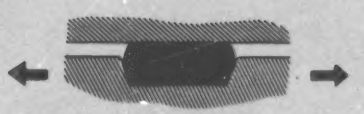


Correct:
Slight Squeeze



Incorrect:
Too-Large Ring

O-Ring Squeeze

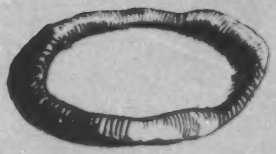


Incorrect:
No Rolling Action

Correct:
Rolling Action

O-Ring Rolling Action

Dynamic Seals
(Continued)



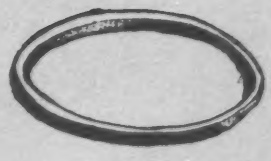
Swollen O-Ring:
Use of Wrong Fluid

Flattened O-Ring:
Use of Low-Grade Rings

Dirty O-Ring:
Poor Storage or Contaminated System

O-Ring Failures

Cut O-Ring:
Shaft Damage or Installed Wrong



Worn O-Ring:
Lack of Lubrication

Cracked O-Ring:
Too Much Heat

Twisted O-Ring:
Installed Wrong

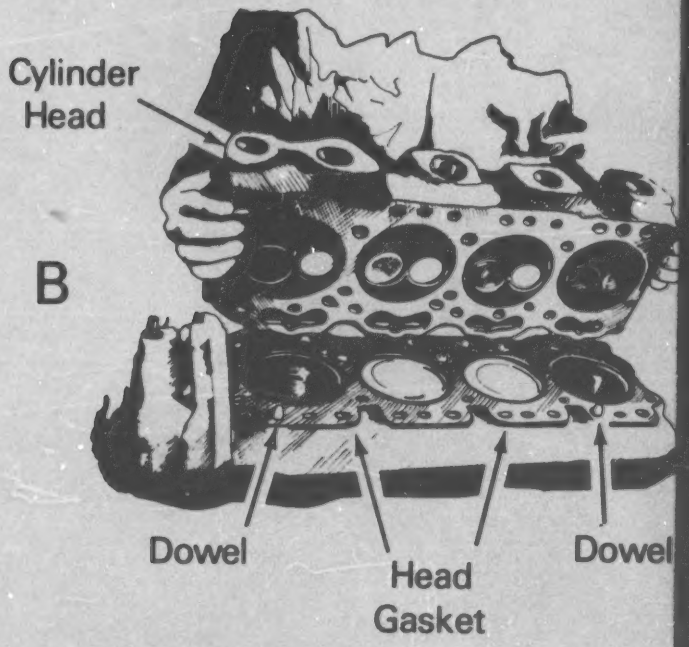
Static Seals

A

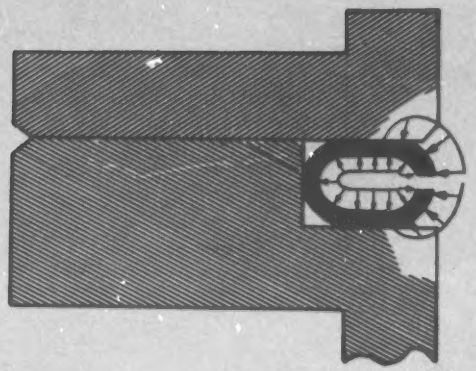
Nonmetallic Gasket
In Low-Pressure Application

B

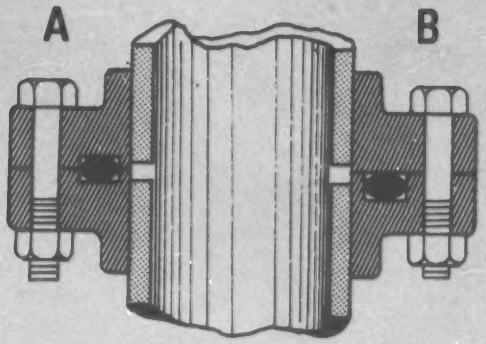
Metallic (Combination) Gasket
On Engine Cylinder Head



Static Seals
(Continued)

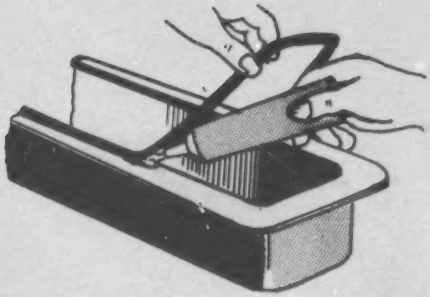


Typical Metallic O-Ring
In Static Use

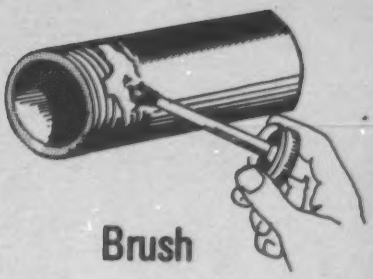


Nonmetallic Static O-Rings
In Flange Joints
(Two Types Of Rectangular
Grooves Shown)

Static Seals
(Continued)

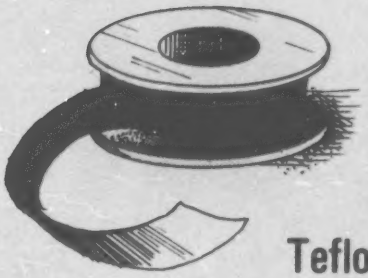


Tube



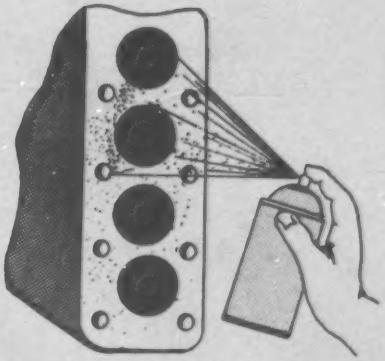
Brush

Sealants
Are "Gaskets"
Which Are Applied In
Liquid Or Paste Form



Teflon Tape

Spray



SEALS
UNIT VI

JOB SHEET #1--INSTALL RADIAL LIP TYPE SEALS

I. Tools and materials

A. Seal installation tools recommended in appropriate service manual

B. Gasket cement

C. Emery cloth

D. Basic hand tool assortment

E. Shop towels (lint free)

F. Appropriate service manual

G. Safety glasses

II. Procedure

A. Clean the shaft or bore area and inspect for damage

B. File or stone any burrs or bad nicks and polish with fine emery cloth to a ground finish

C. Clean area and remove all metal particles

D. Lubricate the seal, especially any lips, and the shaft to ease installation, using the system fluid to lubricate the seal and shaft

(NOTE: On seals with single lips, the lip should normally face in toward the system lubricant. This is usually the garter spring side.)

E. With metal cased seals, coat the seal's outside diameter with a thin film of gasket cement to prevent bore leakage, and do not allow excess cement to run onto sealing lips (Figure 1)

(NOTE: Precoated seals do not require cement on the bore fit.)

Too Much Sealant On Case
Runs Onto Sealing Lips

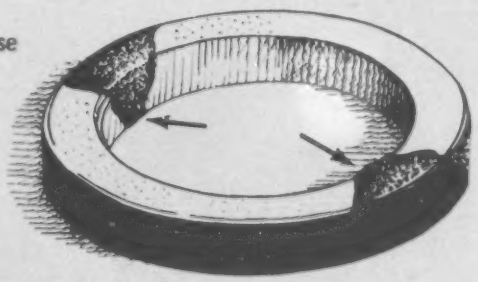


FIGURE 1

JOB SHEET #1

F. Install the seal (Figures 2 and 3)

(NOTE: The use of a factory specified installation tool may be required. This is very important with pressed-in seals. If a seal driving tool is not available, use a circular ring such as an old bearing race that contacts the seal case near the outer diameter, or use a square wooden block. Do not use sharp tools, and never press on the sealing lip, only the outer metal case.)

FIGURE 2

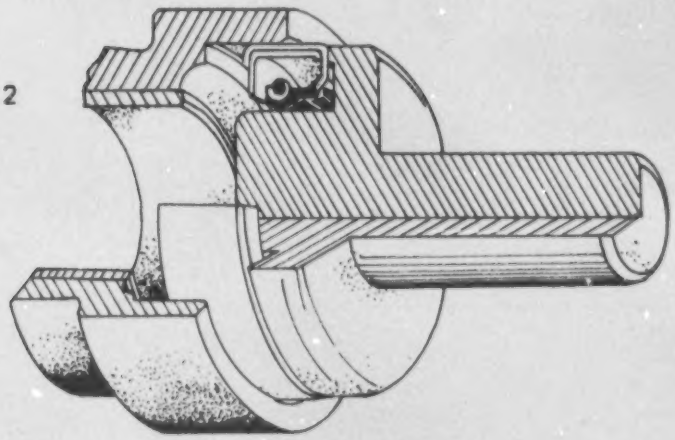
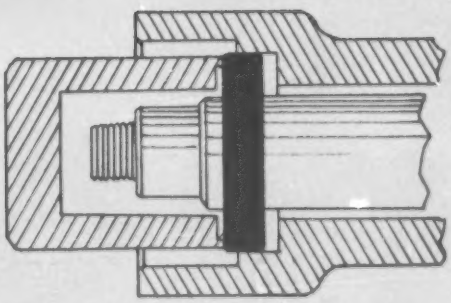


FIGURE 3



JOB SHEET #1

G. Protect the sealing lip when installing the seal over sharp corners of shafts, keyways, or splines (Figures 4 and 5)

(NOTE: Shim stock can also be used to protect seals when installing them over sharp edges such as shaft splines. Place rolled plastic shim stock over the sharp edge, then pull it out after the seal is in place.)

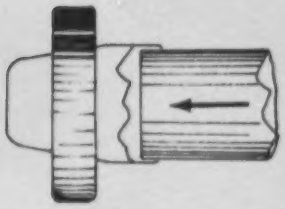


FIGURE 4

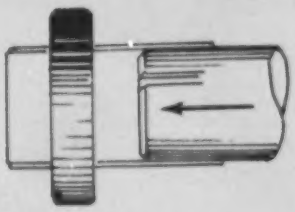


FIGURE 5

H. Drive the seal in evenly to prevent "cocking" of the seal (Figures 6 and 7)

(NOTE: A cocked seal allows oil to leak out and dirt to enter as shown. Be careful not to bend or "dish" the flat metal area of metal cased seals. This causes the lips to be distorted.)

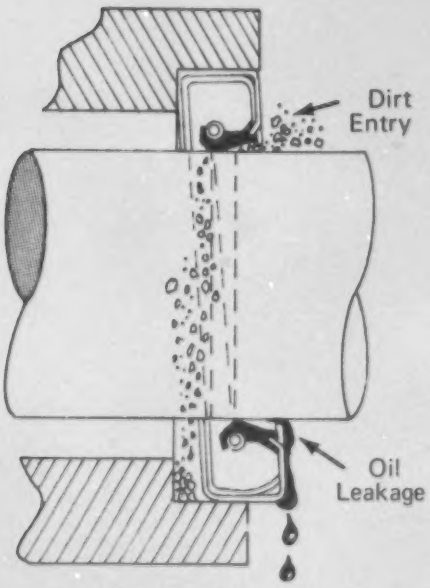


FIGURE 6

Cocked Seals Allow Dirt To Enter And Oil To Leak Out

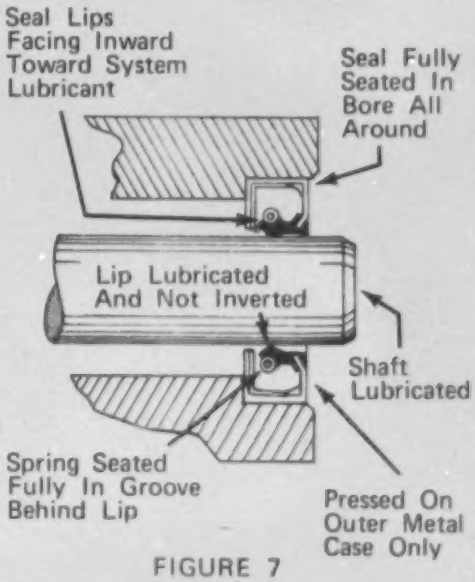


FIGURE 7

JOB SHEET #1

I. After assembly, always check the unit by hand for free operation, if possible, before starting up the system

(NOTE: Try to prevent dirt and grit from falling on shafts and being carried into the seal. This material can quickly damage the seal or score the metal surfaces.)

J. Run in new lip type seal (checking)

(NOTE: When a new lip type seal is installed on a clean shaft, a break in period of a few hours is required to seat the seal lip with the shaft surface. During this period, the seal polishes a pattern on the shaft and the shaft in turn seats the lip contact, wearing away the knife-sharp lip contact to a narrow band. During this period, slight seepage may occur. After seating, the seal should perform without any measurable leakage.)

SEALS
UNIT VI

NAME _____

TEST

1. Match the terms on the right to the correct definitions.

_____a. Moving; relating to force	1.	Static seal
_____b. Without motion; still or fixed	2.	Static
_____c. Similar to gaskets except applied as a liquid or paste	3.	Sealant
	4.	Gasket
_____d. Device which maintains a barrier against the transfer of fluids across two mating surfaces which do not move relative to each other	5.	Dynamic
_____e. Type of static seal		

2. List three uses of seals.

   a.

   b.

   c.

3. Name two basic types of seals and their uses.

   a.

   b.

4. Name three places where dynamic seals are used.

   a.

   b.

   c.

5. Name three places where static seals are used.

   a.

   b.

   c.

6. Match the names of the dynamic seals on the right to their functions.

_____a. Used on systems which have moving shafts

_____b. Used to prevent entry of foreign material into the moving parts of machinery

_____c. Limit leakage by closely controlling the annular clearance between a rotating or reciprocating shaft and stationary bushing

_____d. Depend on surface contact between the seal and the moving part and the seal and the stationary part

_____e. Form a running seal between flat, precision finished surfaces

_____f. Create a seal when squeezed between the throat of a stuffing box and its gland

_____g. Fluid being sealed supplies the pressure to seal the packing against the wearing surface

_____h. Dividing membrane which spans the gap between a moving and stationary member

1. Ring seals
2. Radial lip seals
3. Face seals
4. Molded packings
5. Exclusion seals
6. Clearance seals
7. Diaphragm seals
8. Compression packings

7. List four types of static seals.

a.

b.

c.

d.

8. Name three catagories of sealants.

a.

b.

c.

9. Demonstrate the ability to install a radial lip type seal.

(NOTE: If this activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

SEALS
UNIT VI

ANSWERS TO TEST

1. a. 5
   b. 2
   c. 3
   d. 1
   e. 4
2. a. To keep in fluids
   b. To keep out dirt
   c. To hold pressures or vacuums
3. a. Dynamic--To seal moving parts
   b. Static--To seal fixed parts
4. a. Shafts and rods
   b. Compression packings
   c. Piston rings
5. a. As gaskets
   b. O-rings
   c. Packings
6. a. 2
   b. 5
   c. 6
   d. 1
   e. 3
   f. 8
   g. 4
   h. 7

7. a. Nonmetallic
   b. Metallic
   c. Static O-rings (nonmetallic)
   d. Static O-rings (metallic)
8. a. Hardening types
   b. Nonhardening types
   c. Tapes
9. Performance skill evaluated to the satisfaction of the instructor

CYLINDER HEAD ASSEMBLY
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to disassemble, inspect, recondition, and assemble a cylinder head and its containing parts. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with the cylinder head to the correct definition.
2. Name major parts usually found in a cylinder head assembly.
3. Name three forms of cylinder head castings that may be found on a diesel engine.
4. Identify the primary parts of a valve assembly.
5. List two types of valve rotators.
6. Match valve arrangement to the type of engine head.
7. List two locations for turbulence chambers in an engine.
8. Identify three forms of engine valves.
9. Demonstrate the ability to:
   a. Remove, inspect, and install a cylinder head.
   b. Disassemble and service valve train.
   c. Service valve guides, valve seats, valve seat inserts, and assemble valve train.

CYLINDER HEAD ASSEMBLY
UNIT I

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined in the job sheets.

G. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete job sheets.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Valve Assembly
2. TM 2--Valve Rocker Arm Assembly
3. TM 3--Energy Cell
4. TM 4--Valve and Fuel Injector

5. TM 5--Primary Parts of a Valve Assembly
6. TM 6--Valve Rotators
7. TM 7--Valve Arrangements and Turbulence Chambers
8. TM 8--Forms of Engine Valves

D. Job sheets

1. Job Sheet #1--Remove, Inspect, and Install Cylinder Head
2. Job Sheet #2--Disassemble and Service Valve Train
3. Job Sheet #3--Service Valve Guides, Valve Seats, Valve Seat Inserts, and Assemble Valve Train

E. Test

F. Answers to test

II. References:

A. *Fundamentals of Service.* Moline, Illinois: Deere and Company, 1972.

B. *Shop Manual.* Columbus, Indiana: Cummins Engine Company, 1974.

C. Kates, Edgar J. *Diesel and High-Compression Gas Engines.* Chicago: American Technical Society, 1974.

CYLINDER HEAD ASSEMBLY
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Service--To clean, inspect, lubricate, and/or adjust

B. Poppet valve--Disk with a stem that rises perpendicularly to or from its seat and is opened by a cam and closed by a spring (Transparency 1)

C. Valve seat--That part in the head upon which the valve face rests to close the port (Transparency 1)

D. Valve guide--Hole through which the stem of the valve passes (Transparency 1)

(NOTE: Some guides are pressed into place and others are drilled into head metal.)

E. Valve spring--Helical spring used to close the valve (Transparency 1)

F. Valve spring retainers--Holds the valve spring on the valve stem

G. Rocker arm shaft--Serves as a fulcrum for rocker arms (Transparency 2)

H. Rocker arm--Lever that transmits the action of the cam to the stem of valves (Transparency 2)

I. Rocker arm assembly--Shaft, rocker arm, and cam follower (Transparency 2)

J. Cam follower--Intermediate contact between camshaft and valve stem (Transparency 2)

(NOTE: This is sometimes called a valve lifter.)

K. Energy cell--Special removable combustion chamber for high speed diesel engines (Transparency 3)

L. Turbulence--High velocity swirling of air within the combustion chamber

M. Valve seat angle--Angle between the seat surface and the cylinder head surface, either 30 or 45 degrees

N. Torque--A twisting effort

INFORMATION SHEET

O. Torque wrench--Wrench used to draw nuts to a specified tension by measuring the twisting effort in foot-pounds

P. Foot-pound--Equivalent to raising one pound a distance of one foot

Q. Fuel injector--Meters and sprays fuel into the combustion chamber (Transparency 4)

R. Fuel injection nozzle--Injects fuel under high pressure.

II. Major parts usually found in a cylinder head assembly (Transparency 4)

A. Intake valve

B. Exhaust valve

C. Rocker arm

D. Fuel injector or nozzle

E. Cam followers

F. Fuel injector tube

G. Valve guides

H. Valve seats

III. Forms of cylinder head castings

A. Single

(NOTE: This covers one cylinder.)

B. Multiple

(NOTE: This covers two or more cylinders.)

C. One piece

(NOTE: This covers all cylinders.)

IV. Primary parts of a valve assembly (Transparency 5)

A. Split collar retainers (valve keepers)

B. Valve spring cup

C. Valve spring

D. Valve

INFORMATION SHEET

V. Types of valve rotators (Transparency 6)

A. Release type

B. Positive type

VI. Typical valve arrangements (Transparency 7)

A. I-Head--Both valves above cylinder

B. H-Head--Both valves above angled cylinders (V-block)

C. F-Head--One valve above and one to side of cylinder

D. L-Head--Both valves to side of engine (valve in block)

(NOTE: The F-Head and L-Head are not used much due to the trend toward valve-in-head engines.)

VII. Locations of turbulence chambers (Transparency 7)

A. Chamber in cylinder head

B. Chamber in piston

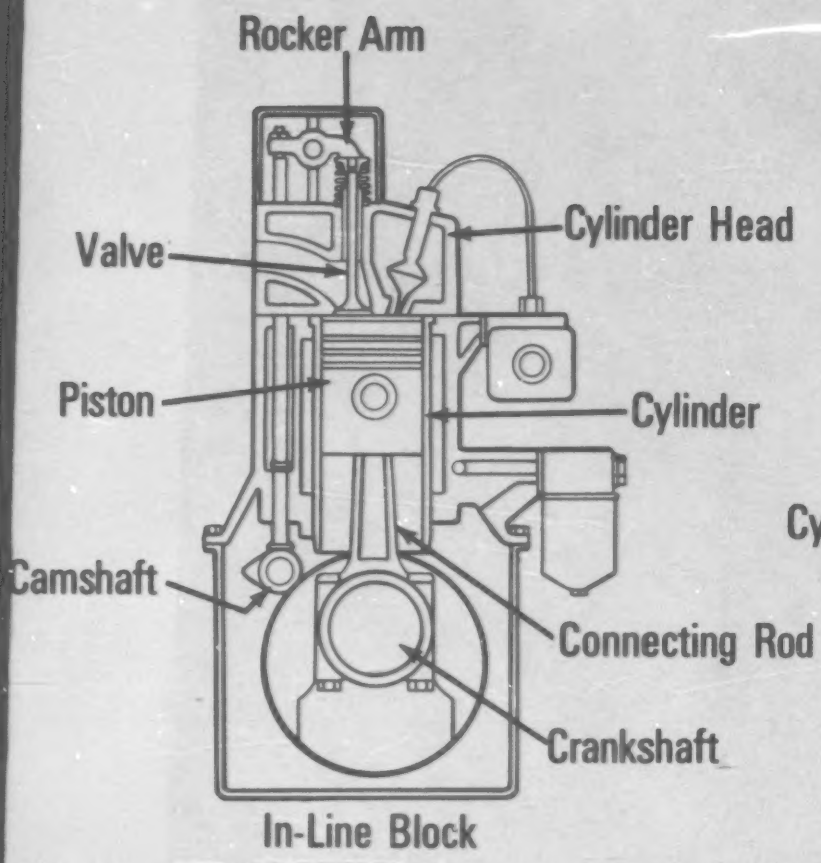
VIII. Forms of valves (Transparency 8)

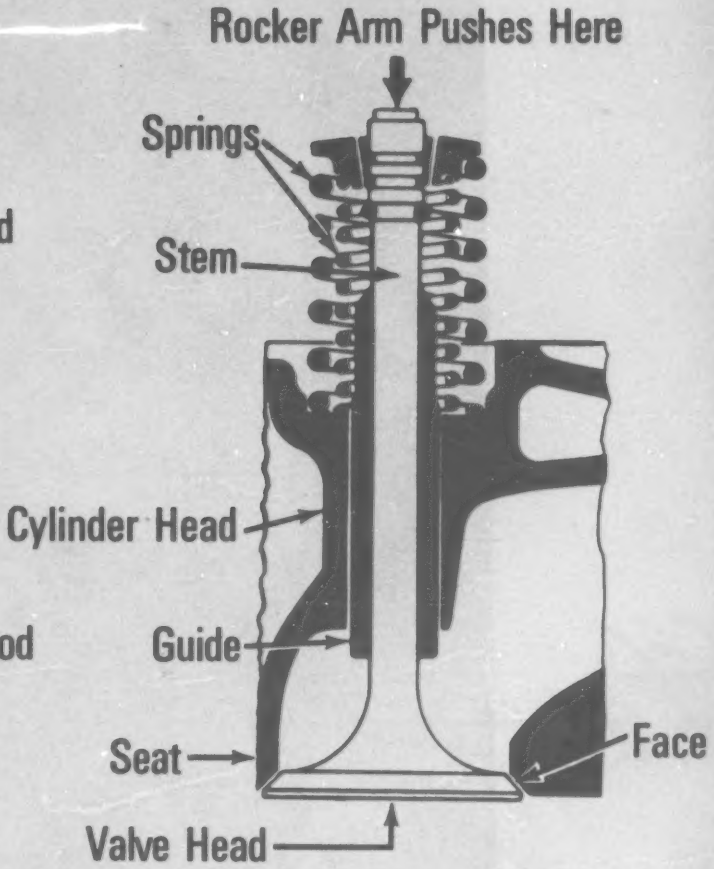
A. Standard

B. Tulip

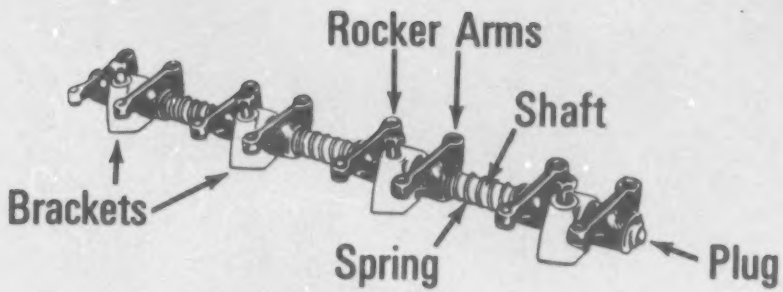
C. Flat-top

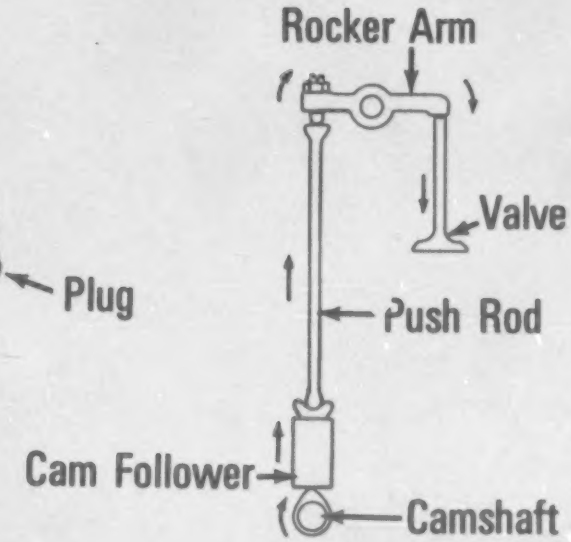
Valve Assembly





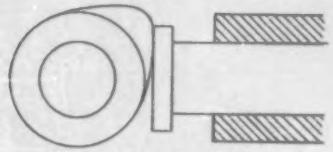
Valve Rocker Arm Assembly



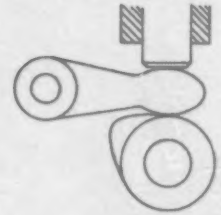


Roller-Type Follower

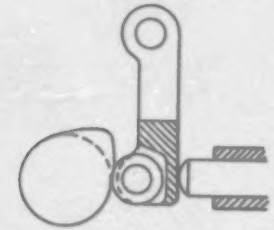
Flat or Mushroom Follower



Pivoted Follower

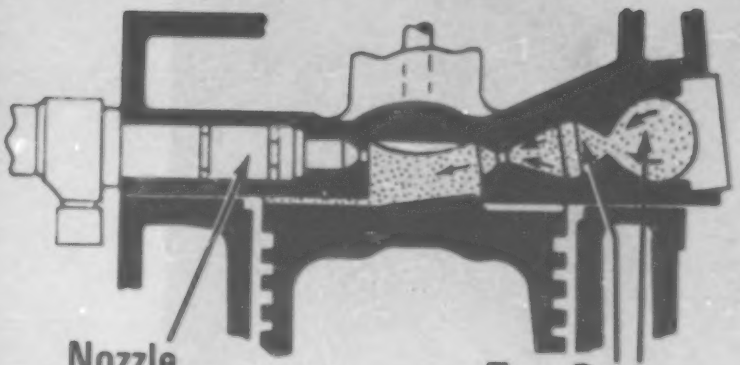


Pivoted Pin Follower with Roller

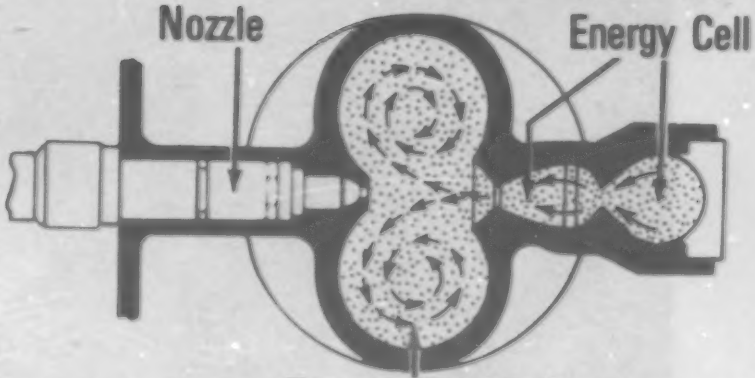


Energy Cell

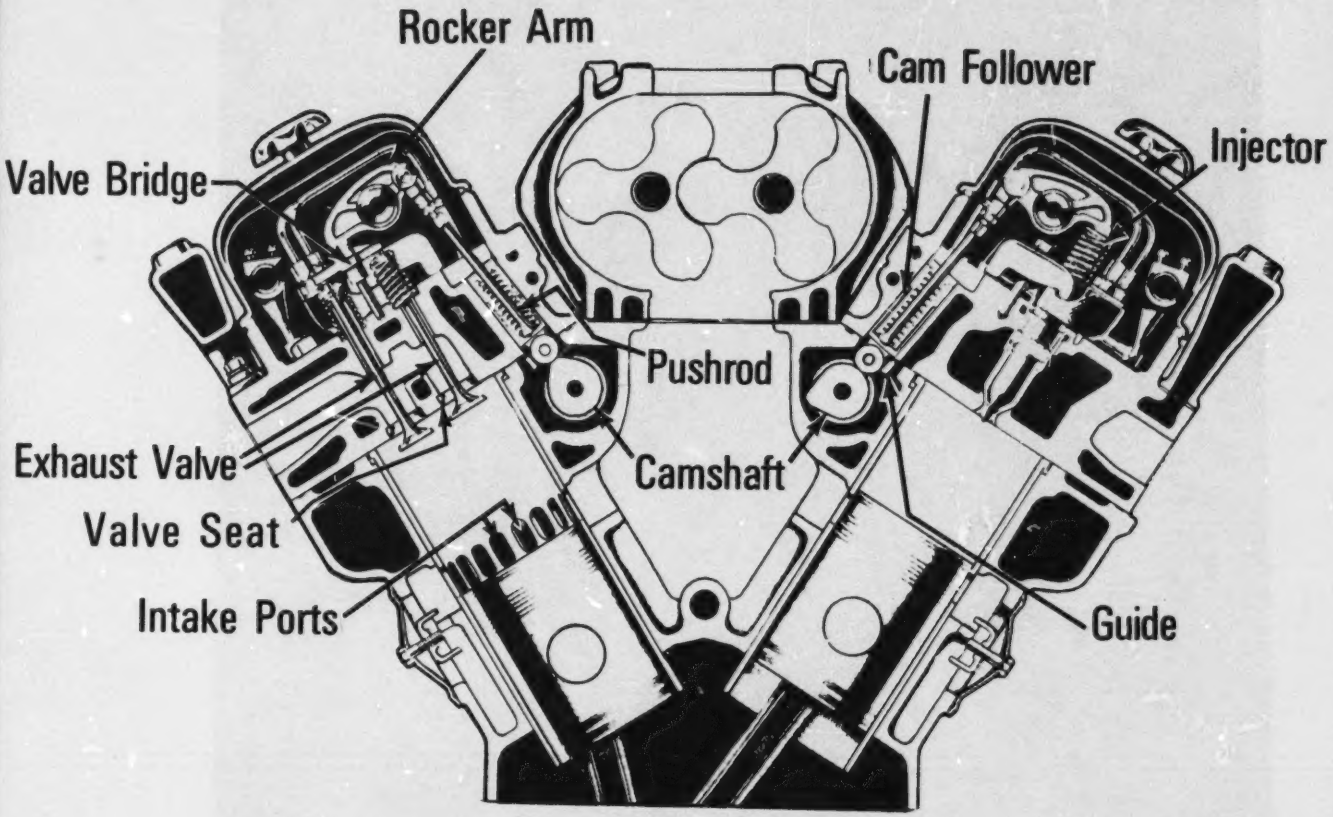
Side View



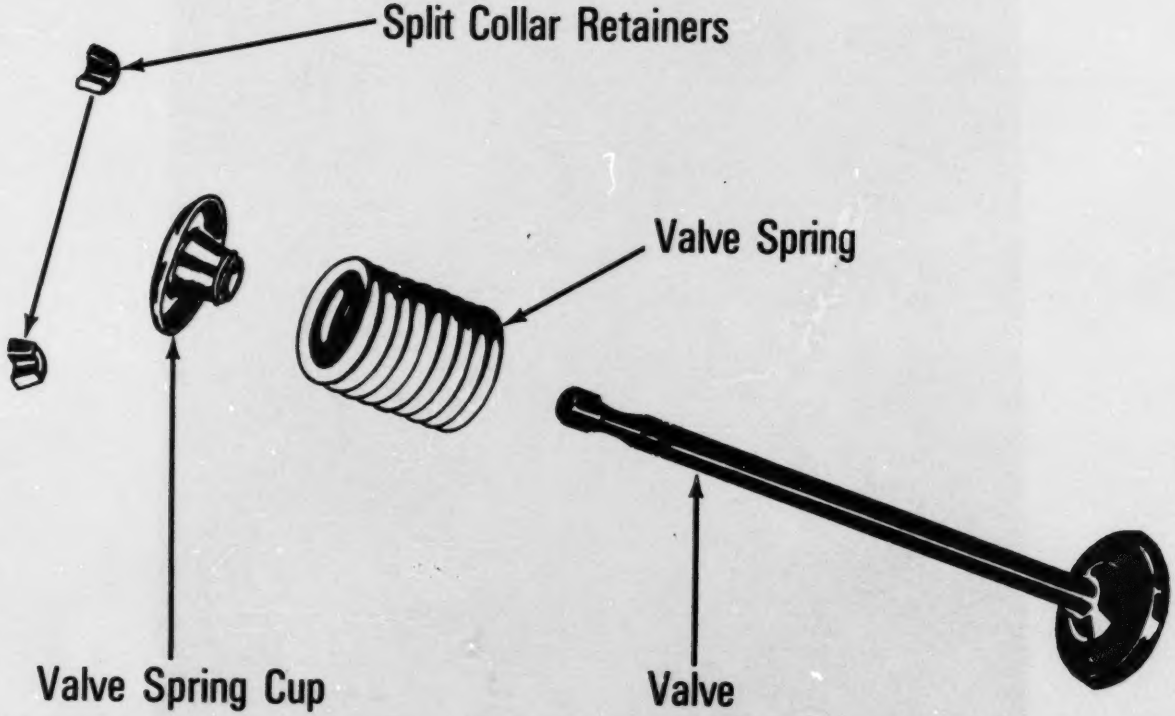
Top View



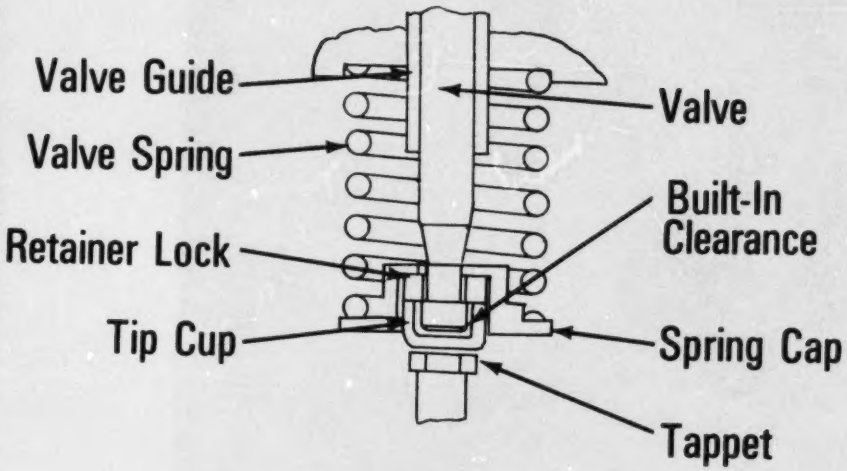
Valve and Fuel Injector



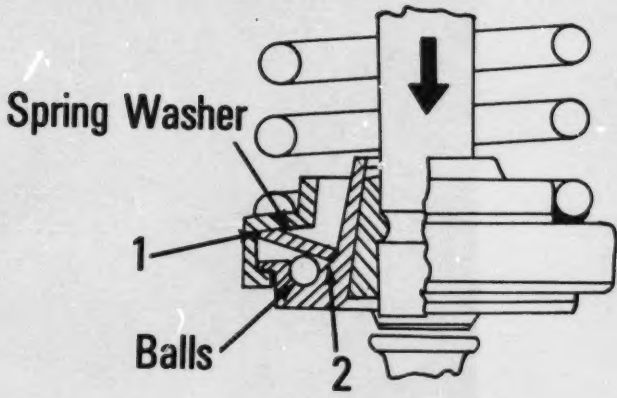
Primary Parts of a Valve Assembly



Valve Rotators



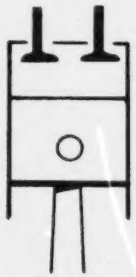
Release–Type



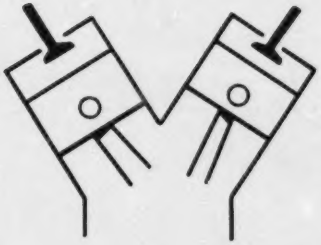
Positive–Type

Valve Arrangements and Turbulence Chambers

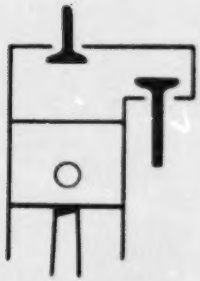
I-Head



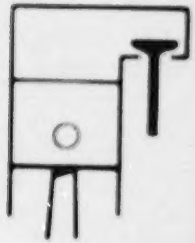
H-Head



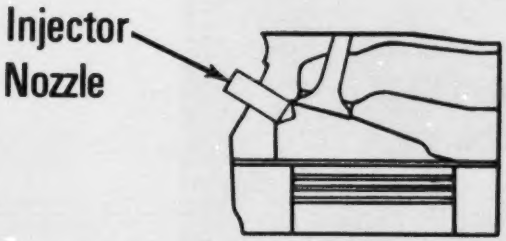
F-Head



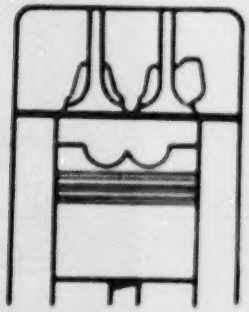
L-Head



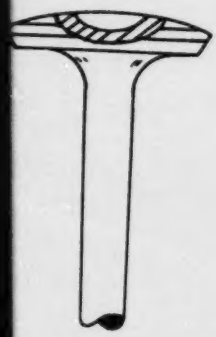
Turbulence Chamber
in Cylinder Head



Turbulence Chamber
in Top of Piston

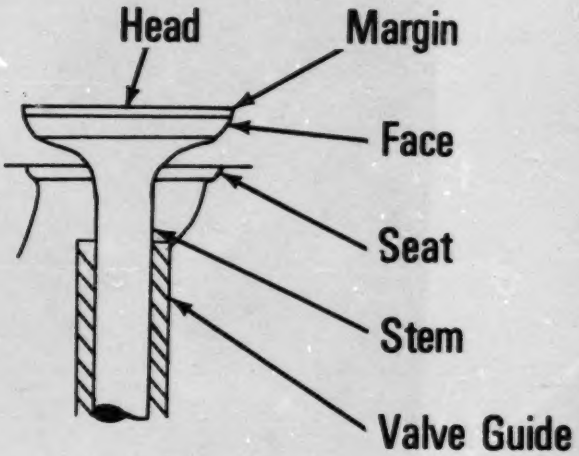


Forms of Engine Valves



Standard

Tulip



Flat-Top

CYLINDER HEAD ASSEMBLY
UNIT I

JOB SHEET #1--REMOVE, INSPECT, AND INSTALL CYLINDER HEAD

I. Tools and materials

A. Steam supply

B. Compressed air supply

C. Chain hoist of sufficient capacity

D. Brass hammer

E. Torque wrench

F. Straight edge

G. Feeler gauge

H. Head gasket scraper

I. Wire brush

J. Basic hand tool set

K. New head gasket

L. Shop towels

M. Eye Protection

II. Procedure

A. Remove cylinder head

1. Check for oil, water, fuel, or compression leaks around cylinder head

2. Steam clean the engine

3. Drain coolant from engine

4. Remove accessories attached to cylinder head, allowing a clear place to work

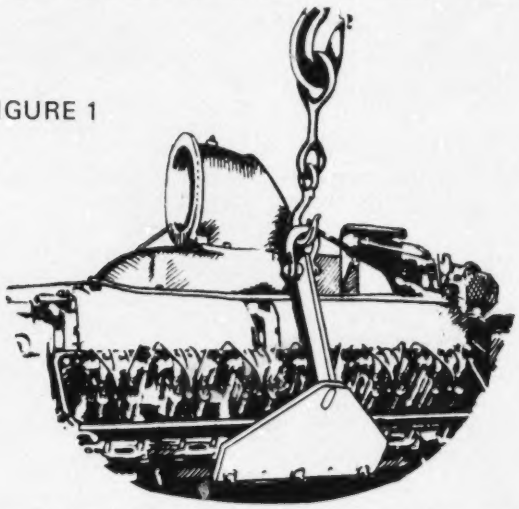
JOB SHEET #1

5. Remove rocker arm cover and rocker arm assembly, if used

6. Remove cylinder head studs as suggested by manufacturer's specifications

7. Attach suitable lifting device to head (Figure 1)

FIGURE 1



8. Break head loose using suitable pry bar and location

   (CAUTION: Do not pry on the contact surfaces.)

9. Place cylinder head in head holding fixture or equivalent and reinstall assessories

B. Inspect cylinder head

1. Clean the cylinder head and contact surfaces

2. Clean mating surfaces of the block and head thoroughly

3. Check for damage to the sealing surfaces of the head or block

4. Check liner protrusion for proper specification

5. Clean all carbon deposits from the head by scraping or brushing with a wire brush

6. Check for lime deposits in water passages and remove soft plug, if used

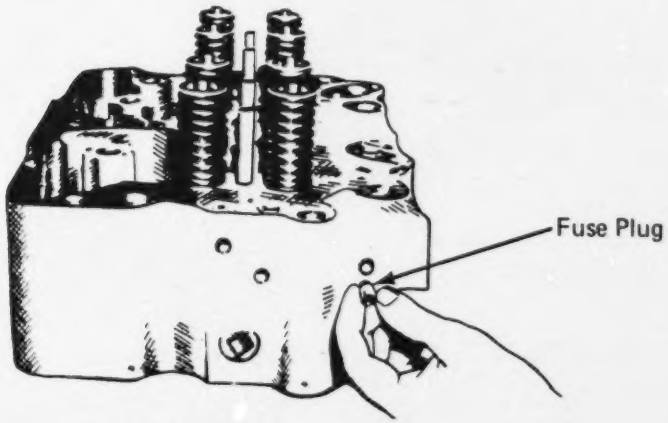
   (NOTE: Use a recommended solution and dip the head to clean out scale and lime.)

JOB SHEET #1

7. Examine fuse plug for signs of overheating (Figure 2)

(NOTE: Fuse plugs contain a metal alloy center that melts if engine is overheated.)

FIGURE 2



8. Inspect and replace soft plug as needed

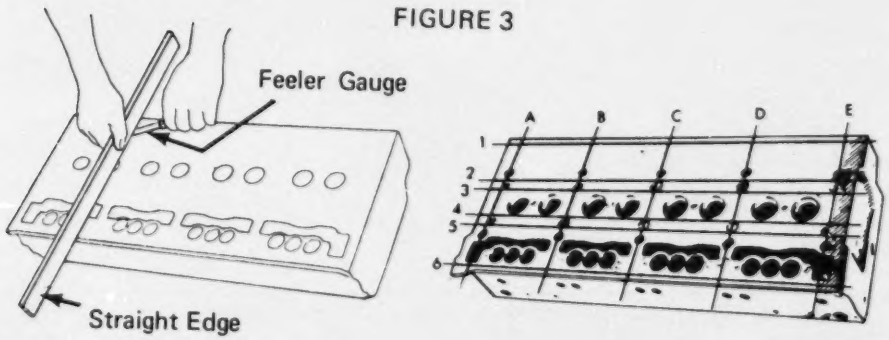
9. Install new plug if metal alloy has melted

(NOTE: If fuse plug has melted, check carefully for further damage.)

10. Use a heavy straight edge and feeler gauge to check for warpage at each end and between all cylinders

(NOTE: Also check for end-to-end warpage in at least six places. See Figure 3.)

FIGURE 3



JOB SHEET #1

11. Decide whether to reinstall head or reface it

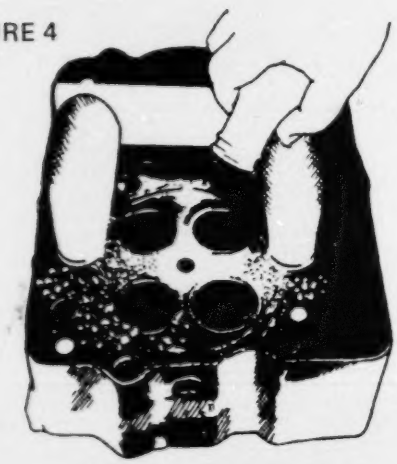
(NOTE: Consult the engine technical manual for refacing limits.)

12. Check head for leaks or cracks

a. Water and air pressure method--Seal the head and connect to an air hose. Immerse in hot water (180 - 200°F) for fifteen minutes. Leaks are detected by any air bubbles which appear in the water

b. Magnetic crack detector method--The magnetic crack detector is placed over the suspected area, setting up a magnetic field (Figure 4)

FIGURE 4



(NOTE: Fine white metallic powder is then sprinkled over the area and the tool is rotated 90 degrees. After excess powder is blown off, any cracks are clearly shown in white.)

C. Install cylinder head

1. Inspect the cylinder head and contact surfaces

2. Inspect for scratches or nicks on the sealing surfaces of the head and block

3. Inspect and clean cylinder head cap screws and threads

JOB SHEET #1

4. Install new cylinder head gasket

   (NOTE: Follow engine manufacturer's recommendation for applying a sealing compound to one or both sides of the head gasket. Check to be sure that water passage holes are aligned with holes in block. Use aligning dowels if required.)

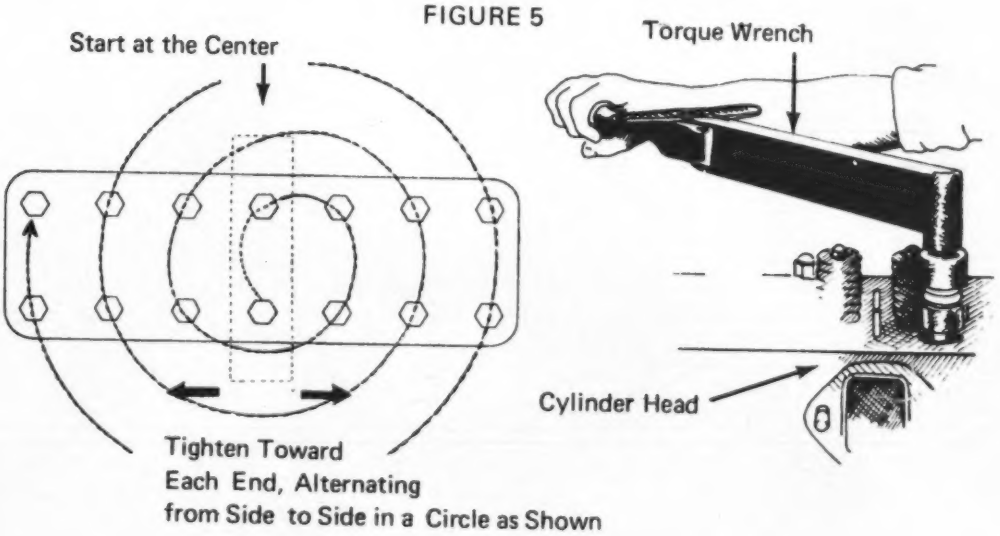
5. Set head squarely on block without disturbing the head gasket

6. Clean and lightly oil bolts or studs

7. Start the stud nuts or cap screws and tighten down finger tight

8. "Snug" down in the correct sequence (see manufacturer's manual) from center of head out (Figure 5)

FIGURE 5



9. Tighten each nut

   (NOTE: Refer to engine manual for torquing procedures. After the engine has been running a few hours, retighten the stud nuts in the correct sequence with the torque wrench.)

CYLINDER HEAD ASSEMBLY
UNIT I

JOB SHEET #2--DISASSEMBLE AND SERVICE VALVE TRAIN

I. Tools and materials

A. Valve spring compressor

B. Steam supply

C. Compressed air supply

D. Bench grinder

E. 0-1 inch micrometer

F. Valve spring tester

G. Dial indicator

H. Basic hand tool set

I. Board with set of numbered holes for valves

J. Crocus cloth

K. Eye protection

II. Procedure

A. Remove valve

1. Steam clean complete head assembly

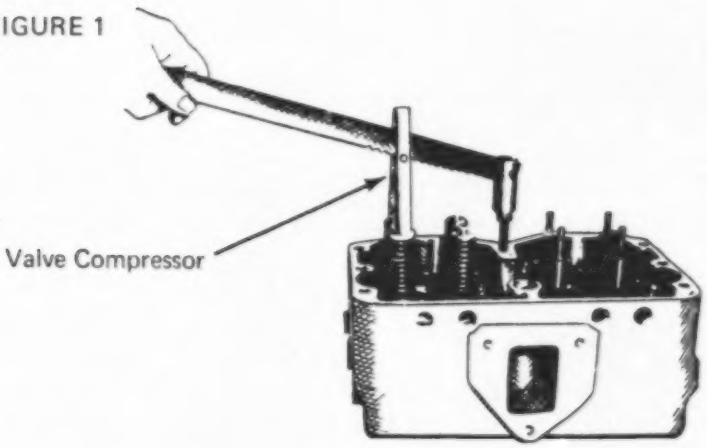
2. Dry with compressed air

3. Place cylinder head in head holding device or equivalent

JOB SHEET #2

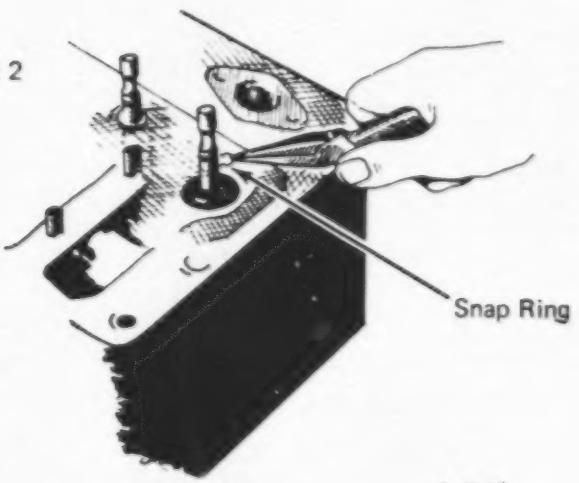
4. Compress one valve spring at a time with valve compressor (Figure 1)

FIGURE 1



5. Tap valve lightly to loosen; then remove split collar retainers
6. Remove spring cup
7. Remove spring
8. Remove snap ring and seal, if used (Figure 2)

FIGURE 2



JOB SHEET #2

9. Remove valve from bottom of cylinder head

10. Use a board with a set of numbered holes drilled in it and place valves in holes in their correct order

(CAUTION: Do not mix.)

B. Clean valves

1. Hold each valve firmly against a wire wheel on a bench grinder, or use glass bead or sandblast method

2. Remove all carbon from valve head, face, and stem

3. Polish valve stems with crocus cloth

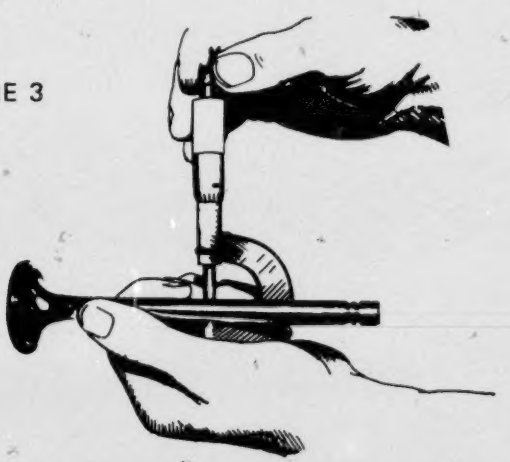
(NOTE: Do not use wire brush on stem bearing surface.)

C. Inspect and test valves

1. Inspect valves

a. Use 0-1 inch micrometer to measure the valve stem (Figure 3)

FIGURE 3



b. If diameter is less than specified in manufacturer's manual, discard valve and valve guide

(NOTE: See Job Sheet #3 for valve guide replacement.)

JOB SHEET #2

2. Test valves

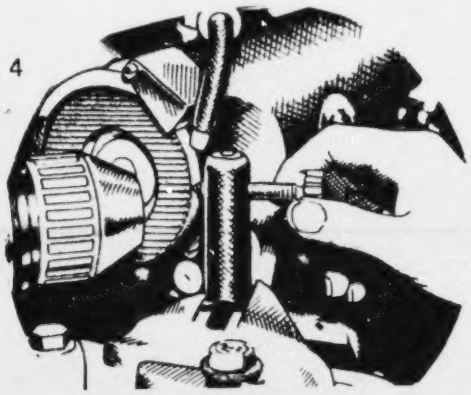
   a. Hold the valve by the stem, head down

   b. Strike sharply on stem end with hammer; if fracture exists, the head will break off

D. Reface valves

1. Dress wheel, if necessary (Figure 4)

FIGURE 4



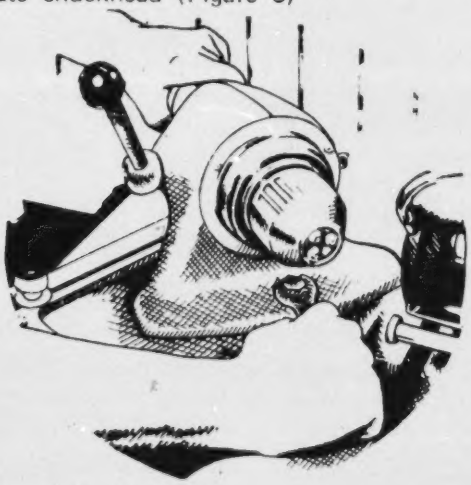
   a. Place dressing attachment against stop bar on grinding head and tighten wing nut

   b. Turn on motor and take light, steady cuts across wheel

   (NOTE: Use coolant as required by manufacturer.)

2. Locate chuckhead (Figure 5)

FIGURE 5



JOB SHEET #2

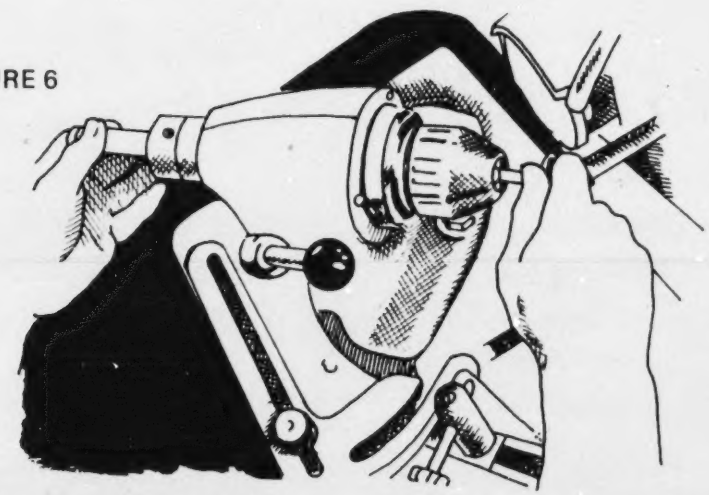
a. Locate chuckhead at the exact angle you wish to refinish valve

(NOTE: Refer to manufacturer's specifications.)

b. Lock chuckhead with hex nut

3. Chuck valve (Figure 6)

FIGURE 6



(CAUTION: Special care should be taken when working with sodium filled exhaust valves.)

a. Open chuck sleeve and insert valve so that rollers touch just above the worn part of the stem

b. Set aligner for proper length of valve

c. Close chuck sleeve to contact stem

d. Depress lever and close chuck sleeve about 1/8 turn

(NOTE: Use according to manufacturer's specifications.)

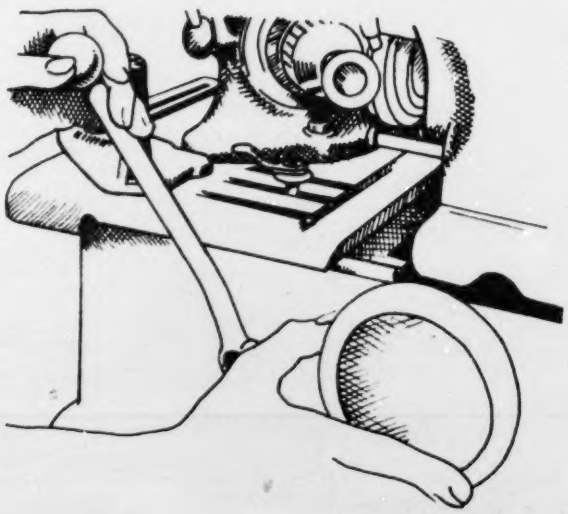
e. Press valve firmly back into aligner and release lever

f. Tighten by hand to desired tension

JOB SHEET #2

4. Grind valves (Figure 7)

FIGURE 7



a. Switch on motor

b. Advance valve in front of grinding wheel until wheel just touches valve

(NOTE: Adjust coolant nozzle as required.)

c. Set micrometer on feed screw at zero

d. Begin grinding at left side of wheel, moving valve slowly and steadily across wheel then back again

e. Take light cuts by feeding the wheel up to the valve .001 or .002 at a time

f. Remove just enough material to make a clean, smooth face

g. When valve face is trued, advance to right until top edge of valve is flush with right hand edge of wheel

(CAUTION: Do not let valve leave the stone.)

JOB SHEET #2

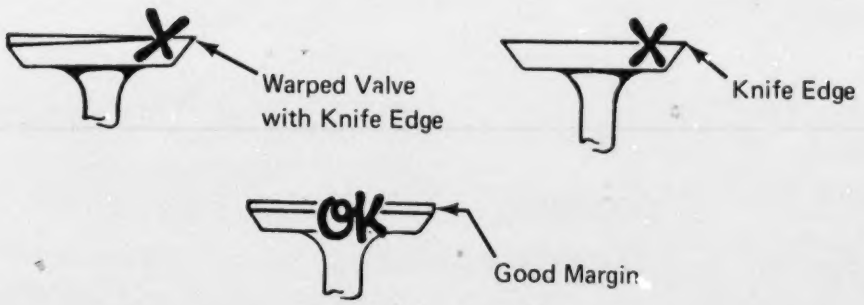
h. Stop a second or two, then back grinding wheel away from valve

i. Repeat steps above for other valves

(NOTE: Keep valves in numbered rack to make sure you return them to their own guides.)

j. Replace any valve that cannot be entirely refaced while keeping a good valve margin (Figure 8)

FIGURE 8



(CAUTION: Avoid a knife edge around part or all of the valve head. See Figure 8.)

E. Inspect valve spring

1. Inspect for:

a. Wear on the casting where springs rotate

b. Wear on the spring caps

c. Wear on ends of spring

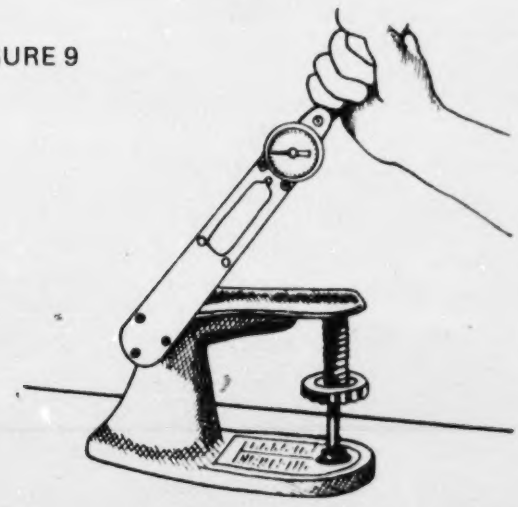
d. Warped springs

JOB SHEET #2

2. Test spring tension

   a. Mount valve spring on spring tester (Figure 9)

FIGURE 9



   b. Measure spring length by means of manufacturer's standards

   c. Compress valve spring

   (NOTE: If valve springs compress to dimensions shown in manufacturer's table at less than load indicated under "worn limits," valve spring should be discarded.)

CYLINDER HEAD ASSEMBLY
UNIT I

JOB SHEET #3--SERVICE VALVE GUIDES, VALVE SEATS, VALVE SEAT INSERTS, AND ASSEMBLE VALVE TRAIN

I. Tools and materials

A. Basic hand tool set

B. Electric hand drill

C. Rotary wire cleaning brush

D. Valve seat grinding kit

E. 0-1 inch micrometer

F. Small bore gauge

G. Bluing or lead pencil

H. Shop towels

I. Eye protection

II. Procedure

A. Service valve guides

1. Clean valve guides

a. Use correct size wire brush in an electric drill

b. Run brush up and down the full length of guide (Figure 1)

FIGURE 1

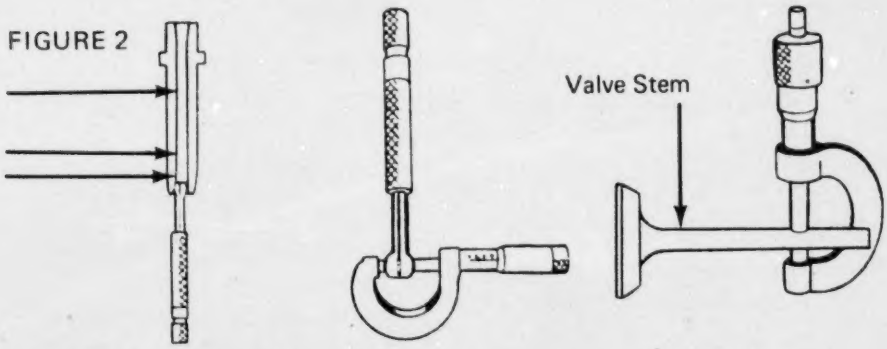
c. Apply a few drops of oil

JOB SHEET #3

2. Inspect valve guides

   a. Measure at different points within the guide (Figure 2)

FIGURE 2



Measure Inside of Guide with Gauge

   b. Read measurement with micrometer

   c. Measure outside of valve stem (Figure 2)

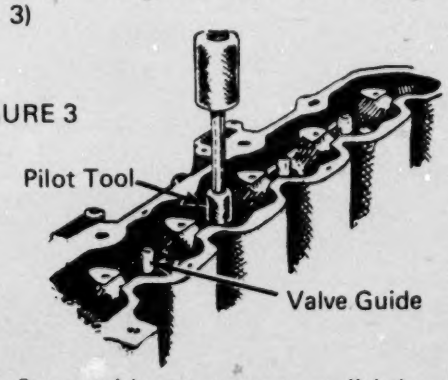
   d. Compare (b) and (c) for clearance

   (NOTE: If guide to stem clearance is more than 50 percent above manufacturer's specifications, replace or knurl and ream the valve guide.)

3. Replace valve guides

   a. Remove old valve guide and install new guides as needed (Figure 3)

FIGURE 3



   (NOTE: Some guides may compress slightly when installed.)

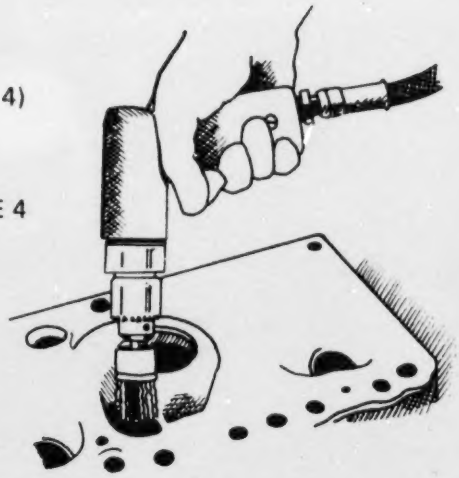
   b. Precision-ream to specifications after installation, if required

JOB SHEET #3

B. Service valve seats

1. Clean valve seats (Figure 4)

FIGURE 4



a. Use an electric hand drill with wire brush to remove all carbon

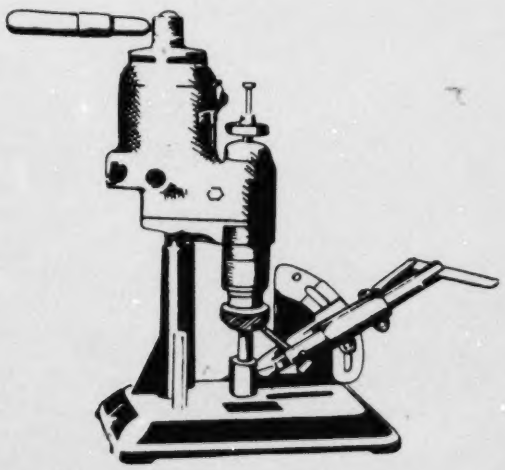
b. Apply kerosene to loosen carbon

c. Check for pitted, burned, or worn seat

2. Dress grinding wheel

a. Set dressing tool at desired angle (Figure 5)

FIGURE 5



b. Put a drop of very light oil on dressing pilot

(CAUTION: Do not get oil on grinding wheel.)

JOB SHEET #3

c. Screw grinding wheel on holder and place on pilot

d. Adjust until wheel just touches diamond

e. Insert driver and bring up to speed

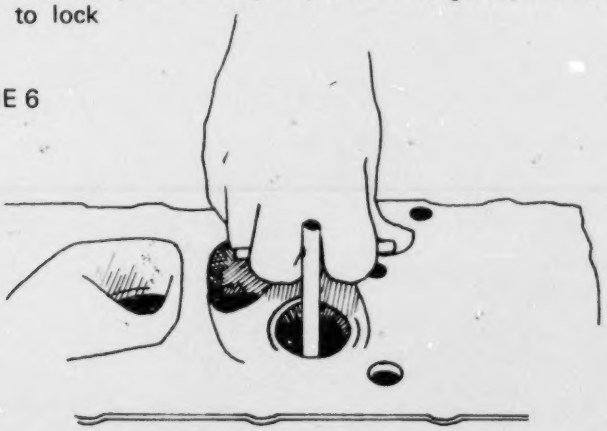
f. Move diamond steadily across wheel, taking light cuts

3. Select tapered pilot (Figure 6)

a. Select largest pilot which will fit snugly into valve guide

b. Place drop of oil on pilot, insert into guide, and twist gently to lock

FIGURE 6

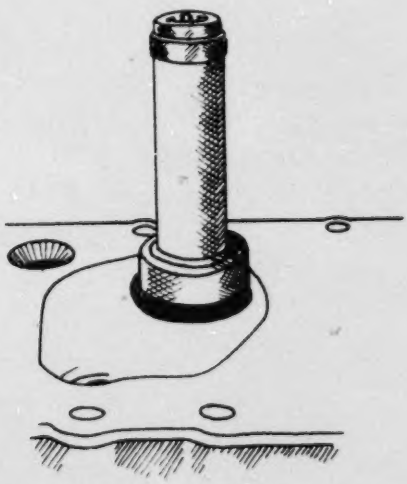


4. Select grinding wheel

a. Screw proper grinding wheel onto holder and place on pilot (Figure 7)

(NOTE: Refer to service manual for size and angle.)

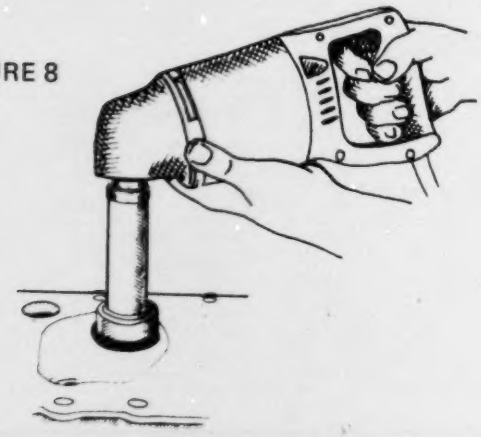
FIGURE 7



JOB SHEET #3

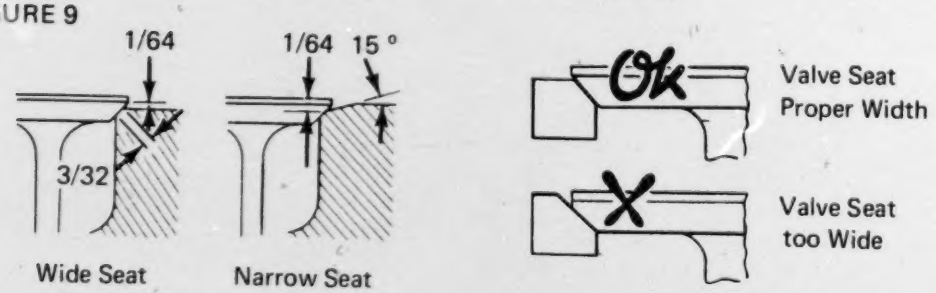
b. Insert driver spindle in holder (Figure 8)

FIGURE 8



c. Grind the valve seat so that little of the valve face is exposed to the combustion chamber (Figure 9)

FIGURE 9



(NOTE: Narrow seat to manufacturer's specifications.)

d. Precautions

1) Do not grind too long, only a few seconds

2) Do not use too much pressure

3) Keep work area clean

4) Check seat width and contact pattern with bluing or lead pencil marks

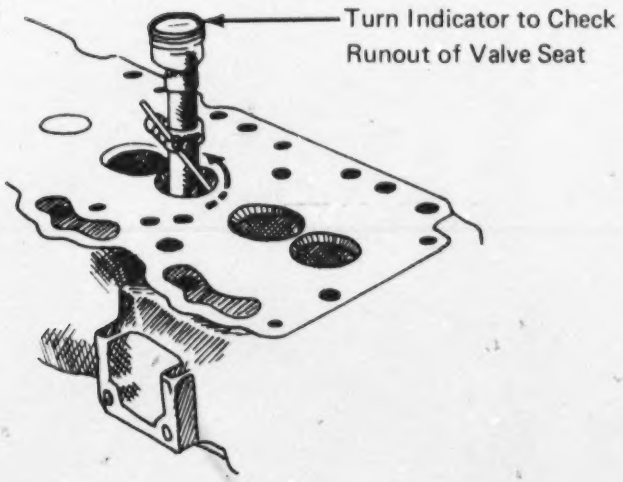
JOB SHEET #3

5) Regrind uneven spots

(NOTE: Lap seats with grinding compound only if necessary.)

6) Check the runout (concentricity) of the valve seat with a dial indicator (Figure 10)

FIGURE 10



(NOTE: Reading must be within specifications shown in the engine technical manual.)

7) Rotate the pilot 90° in the guide and take a second reading

C. Service valve seat inserts

1. Clean, inspect and grind using same method as with bored valve seats in (B)

2. Lightly tap head near valve seat, if insert is loose enough to bounce mark for replacement

(NOTE: Replacement of injector sleeves (if used), energy cell (if used), valve seat inserts (if used), and resurfacing of cylinder head is recommended at instructor's option as determined by availability of tools and equipment. See manufacturer's shop manual for special tools required and steps of procedure.)

JOB SHEET #3

D. Assemble valve train

1. Apply oil to valve stems and return to same ports from which they were removed

   (NOTE: Commercial valve stem lubricants are available.)

2. Work the valves back and forth to make sure they slip through easily and seat properly

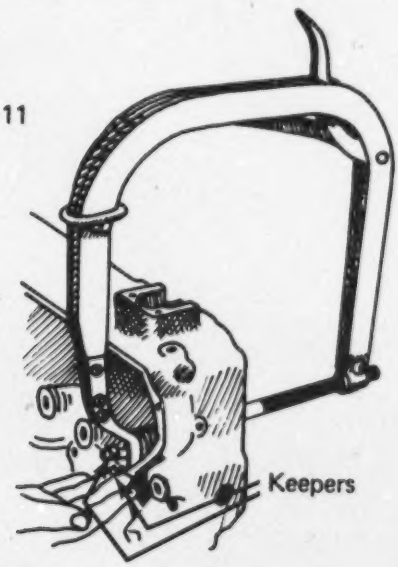
   (NOTE: A properly seated valve will bounce when dropped on its seat.)

3. Install valve seals if required and seat valve springs

   (NOTE: Place wound end of spring to stationary side.)

4. Install new valve keepers, if necessary, making sure they fit properly (Figure 11)

FIGURE 11



5. Pop each spring and valve assembly three or four times by tapping on the end with a soft mallet

CYLINDER HEAD ASSEMBLY
UNIT I

NAME_____

TEST

1. Match the terms on the right to their correct definition.

_____a. To clean, inspect, lubricate, and/or adjust

_____b. Disk with a stem that rises perpendicularly to or from its seat and is opened by a cam and closed by a spring

_____c. That part in the head upon which the valve face rests to close the port

_____d. Hole through which the stem of the valve passes

_____e. Helical spring used to close the valve

_____f. Holds the valve spring on the valve stem

_____g. Lever that transmits the action of the cam to the stem of the valves

_____h. Serves as a fulcrum for rocker arms

_____i. Shaft, rocker arm, and cam follower

_____j. Intermediate contact between camshaft and valve stem

_____k. Special removable combustion chamber for high speed diesel engines

_____l. High velocity swirling of air within the combustion chamber

_____m. Angle between the seat surface and the cylinder head surface, either 30 or 45 degrees

_____n. A twisting effort

1. Valve guide
2. Cam follower
3. Rocker arm
4. Rocker arm shaft
5. Valve spring retainers
6. Service
7. Rocker arm assembly
8. Valve seat
9. Poppet valve
10. Valve spring
11. Valve seat angle
12. Energy cell
13. Foot-pound
14. Fuel injector

_____o. Wrench used to draw nuts to a specified tension by measuring the twisting effort in foot-pounds

_____p. Equivalent to raising one pound a distance of one foot

_____q. Meters and sprays fuel into the combustion chamber

_____r. Injects fuel under high pressure

15. Torque wrench
16. Turbulence
17. Torque
18. Fuel injection nozzle

2. Name five major parts usually found in a cylinder head assembly.

a.

b.

c.

d.

e.

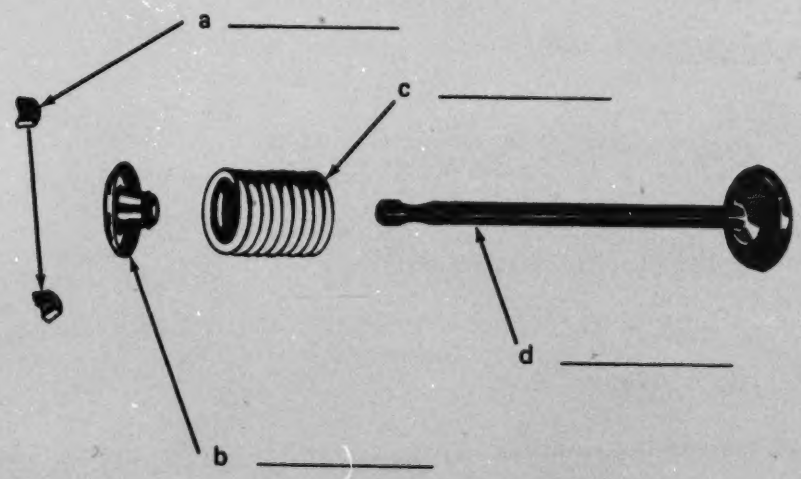
3. Name three forms of cylinder head castings that may be found on a diesel engine.

a.

b.

c.

4. Identify the primary parts in a valve assembly.



5. List two types of valve rotators.

   a.

   b.

6. Match the valve arrangements on the left to the type of engine head.

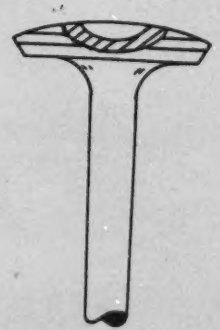
_____	a. Both valves to side of engine	1.	F-Head
_____	b. Both valves above angled cylinders	2.	L-Head
_____	c. Both valves above cylinder	3.	I-Head
_____	d. One valve above and one to side of cylinder	4.	H-Head

7. List two locations for turbulence chambers in the engine.

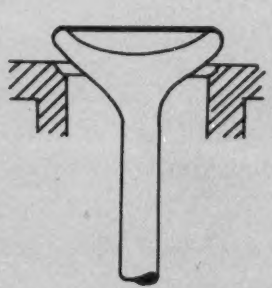
   a.

   b.

8. Identify three forms of engine valves.



a _____



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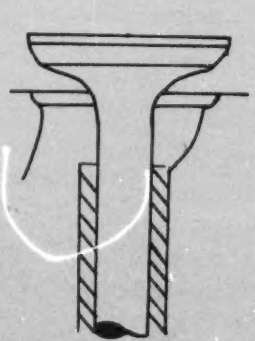


c _____

9. Demonstrate the ability to:

   a. Remove, inspect, and install a cylinder head.

   b. Disassemble and service valve train.

   c. Service valve guides, valve seats, valve seat inserts, and assemble valve train.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

CYLINDER HEAD ASSEMBLY
UNIT I

ANSWERS TO TEST

1.

a.	6	g.	3	m.	11
b.	9	h.	4	n.	17
c.	8	i.	7	o.	15
d.	1	j.	2	p.	13
e.	10	k.	12	q.	14
f.	5	l.	16	r.	18

2. Any five of the following:
   a. Intake valve
   b. Exhaust valve
   c. Rocker arm
   d. Fuel injector or nozzle
   e. Cam followers
   f. Fuel injector tube
   g. Valve guides
   h. Valve seats

3. a. Single
   b. Multiple
   c. One piece

4. a. Split collar retainers (valve keepers)
   b. Valve spring cup
   c. Valve spring
   d. Valve

5. a. Release type
   b. Positive type
6. a. 2
   b. 4
   c. 3
   d. 1
7. a. Chamber in cylinder head
   b. Chamber in piston
8. a. Flat-top
   b. Standard
   c. Tulip
9. Performance skills evaluated to the satisfaction of the instructor

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to service a piston pin and connecting rod and install precision-insert connecting rod bearings. The student should also be able to identify the primary parts of a piston and connecting rod assembly and select the causes of high oil consumption and blow-by. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with piston and connecting rod assemblies to the correct definitions.
2. Identify seven primary parts of a piston and connecting rod assembly.
3. List three functions of the piston.
4. Identify five main parts of a piston.
5. List three functions of piston rings.
6. Name the two types of piston rings.
7. Name three common types of ring joints.
8. Select possible causes of high oil consumption and blow-by.
9. Identify three types of piston pins.
10. Name two types of construction for the cap end of a connecting rod.
11. Discuss the reason for markings on the connecting rod, piston, and bearing cap.
12. Demonstrate the ability to:
    a. Service piston and install piston rings.
    b. Service piston pin and connecting rod.
    c. Install precision-insert connecting rod bearings.

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT II

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined in the job sheets.

G. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete job sheets.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Piston and Connecting Rod Assembly
2. TM 2--Piston Rings
3. TM 3--Blow-By
4. TM 4--Types of Piston Pins
5. TM 5--Connecting Rod Markings

D. Job sheets

1. Job Sheet #1--Service Piston and Install Piston Rings
2. Job Sheet #2--Service Piston Pin and Connecting Rod
3. Job Sheet #3--Install Precision-Insert Connecting Rod Bearings

E. Test

F. Answers to test

II. References:

A. Kates, Edgar J., and Luck, William E. *Diesel and High Compression Gas Engines.* Chicago: American Technical Society, 1972.

B. *Fundamentals of Service: Engines.* Moline, Illinois: Deere and Company, 1972.

C. *Cummins Engine Shop Manual.* Columbus, Indiana: Cummins Engine Company, 1974.

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Piston skirt--Outside part of piston below ring grooves

B. Piston land--Area between ring grooves

C. Piston pin--Ties piston and rod together

D. Piston pin boss--Hole in piston which supports piston pin

E. Ring joints--Clearance between ends of piston rings

F. Blow-by--Combustion gases escaping to the crankcase

G. Lugging--Overloading, causing unusual stress

H. Incandescent--Glowing or burning

I. Knurling--Upsetting the metal to decrease the inside diameter or increase the outside diameter

J. Full floating pin--Piston pin that moves in both rod and piston

K. Plastigage--Soft, oil soluble, plastic thread

II. Primary parts of a piston and connecting rod assembly (Transparency 1)

A. Piston

B. Piston rings

C. Piston pin

D. Piston pin bushing

E. Connecting rod

F. Connecting rod cap

G. Bearing shells

III. Functions of a piston

A. Receives the force of combustion

B. Transmits this force to the crankshaft

C. Carries the piston rings which seal and wipe the cylinder

INFORMATION SHEET

IV. Main parts of a piston (Transparency 1)

- A. Head or crown
- B. Skirt
- C. Ring grooves
- D. Lands
- E. Piston pin boss

V. Functions of piston rings

- A. Forms a gas tight seal between the piston and cylinder
- B. Helps cool the piston by transferring heat
- C. Controls lubrication between piston and cylinder wall

VI. Types of piston rings (Transparency 2)

- A. Compression rings
- B. Oil control rings

VII. Common types of ring joints (Transparency 2)

- A. Step
- B. Angle
- C. Butt

VIII. Causes of high oil consumption and blow-by (Transparency 3)

- A. Piston rings installed wrong
- B. Stuck oil ring
- C. Plugged oil ring
- D. Top ring broken or top groove worn
- E. Overall wear in piston, rings, and cylinder
- F. Physical damage to pistons

INFORMATION SHEET

IX. Types of piston pins (Transparency 4)

A. Fixed--Moves in rod, fastened to piston

B. Semi-floating--Moves in piston, fastened to rod

C. Full floating--Moves in both piston and rod, fastened by spring clips

X. Types of construction for the cap end of a connecting rod (Transparency 5)

A. Square cut

B. Angle cut

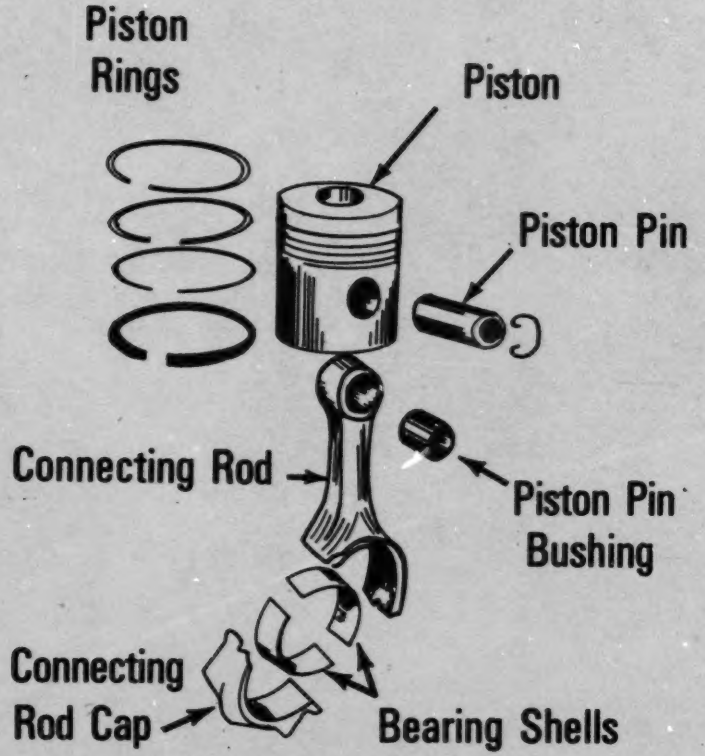
XI. Reasons for markings (Transparency 5)

A. On the piston--To install in same cylinder and on same side from which removed

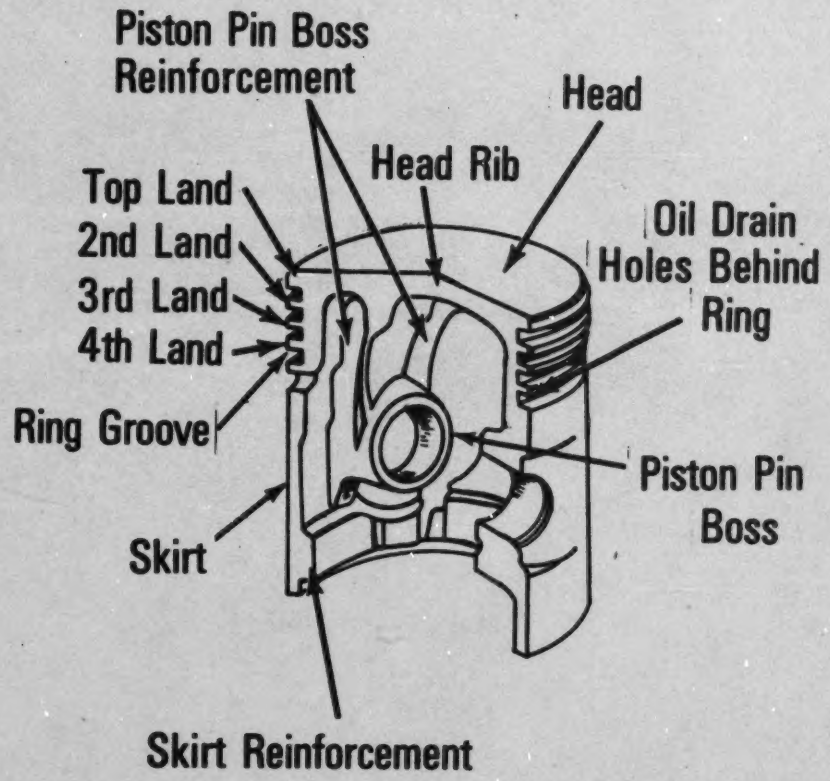
B. On the connecting rod--To install in same cylinder and on same side from which removed

C. On the bearing cap--To install on same rod and on same side from which removed

Piston and Connecting Rod Assembly

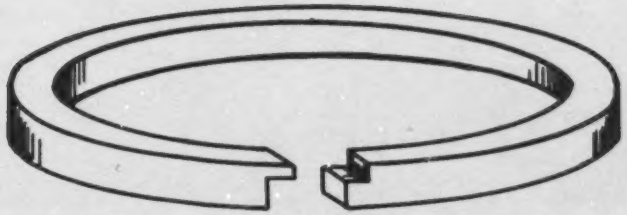


Complete Piston and Connecting Rod Assembly

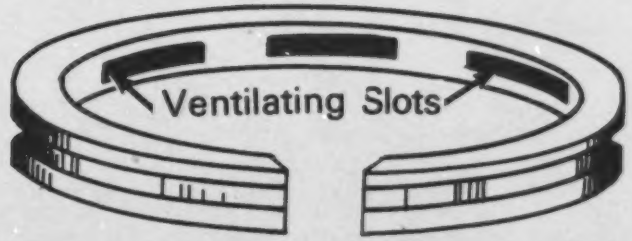


Piston

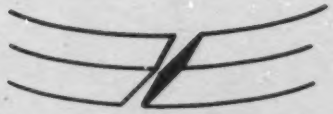
Piston Rings



Compression Ring

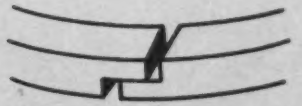


Double–land Beveled and Ventilated Oil Ring



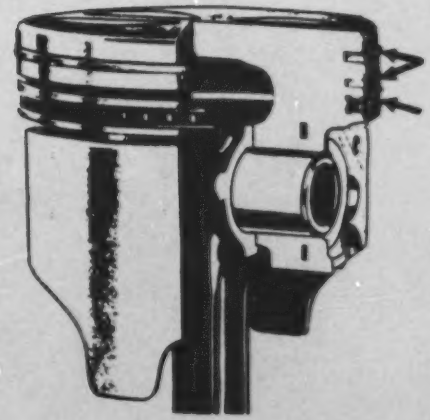
45° Angle Joint

Butt Joint



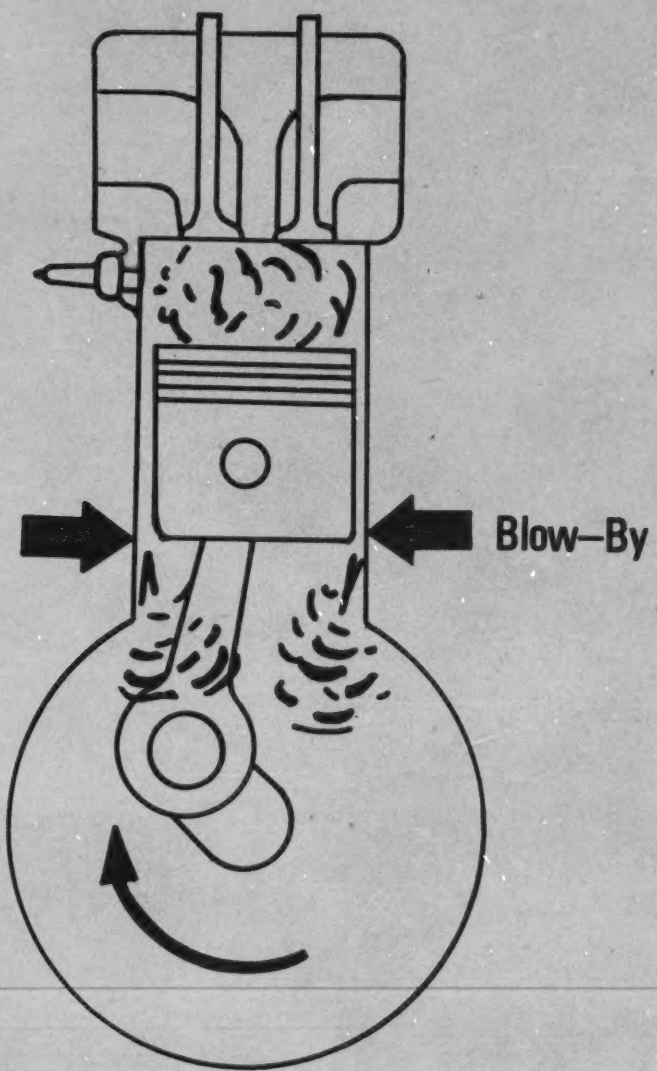
Step Joint

Compression Rings with Simple Joints



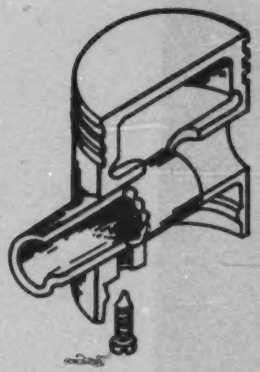
Piston Rings for a Typical Piston

Blow-By



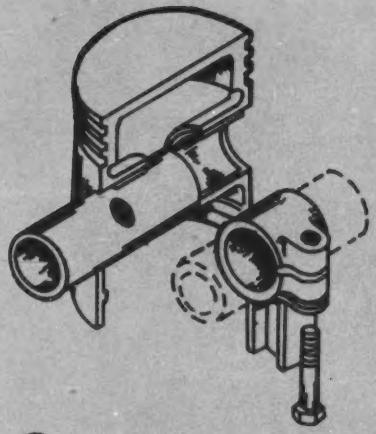
Blow–By of Gases in Cylinder

Types of Piston Pins



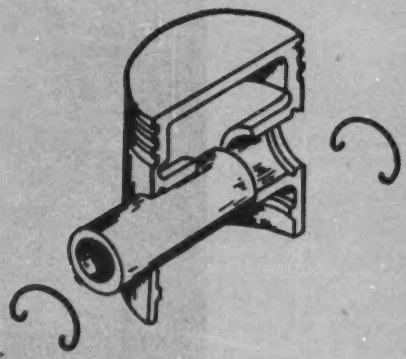
Fixed Pin

Fastened to Piston



Semi-Floating Pin

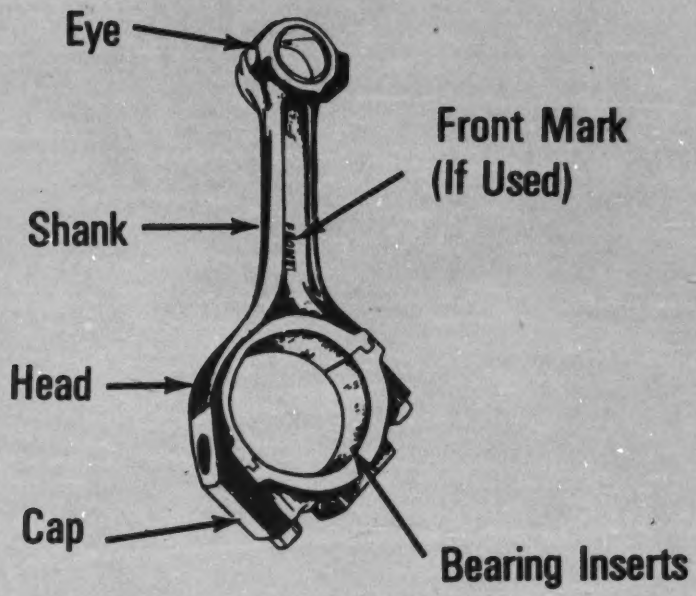
Fastened to Rod



Full Floating Pin

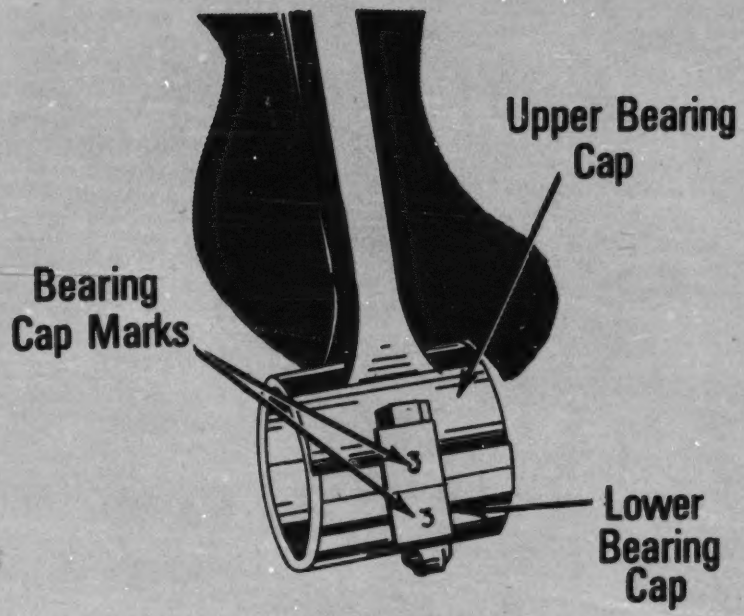
Fastened by Spring Clips

Connecting Rod Markings



Connecting Rod Angle Cut

426



Connecting Rod Square Cut

427

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT II

JOB SHEET #1--SERVICE PISTON AND INSTALL PISTON RINGS

I. Tools and materials

- A. Ring expander
- B. Thickness gauge
- C. Outside micrometers
- D. Bench vise
- E. Chemical cleaning solution
- F. Solvent to remove oil film
- G. Water spray supply
- H. Compressed air supply
- I. Eye protection

II. Procedure

- A. Remove cylinder head assembly and secure liner as necessary
- B. Remove piston
  1. Remove oil level gauge and gauge tube
  2. Remove fuel drain lines and other parts as necessary
  3. Clean the carbon ridge from top of cylinder liner
  4. Rotate the crankshaft clockwise as necessary to gain access to the connecting rod cap
  5. Remove the connecting rod cap and retaining bolts

     (NOTE: Mark rod and cap if not already marked.)
  6. Push the piston upward until the rings clear the cylinder liner

     (CAUTION: Protect the connecting rod journal.)
  7. Lift the piston and connecting rod from the liner

JOB SHEET #1

8. Replace cap on rod after removal

9. Repeat above steps for remaining pistons

C. Remove old rings

1. Clamp connecting rod in a vise using jaw protectors

2. Use a ring expander to remove old rings

D. Disassemble piston

1. Remove piston pin retaining rings, if used

2. Remove piston pin and piston from the connecting rod

E. Clean pistons using one of the following methods

1. Use a chemical solution to soak pistons

a. Use a solvent to remove oil film from pistons

b. Mix the cleaner solution and heat as recommended

c. Soak the pistons in the cleaning solution for specified time

d. Soak for a second period if needed and scrape lightly if needed

(CAUTION: Never use a wire brush.)

e. Drain and spray rinse with water and air

(NOTE: Be sure the piston ring grooves are thoroughly cleaned.)

2. Use glass beads to clean pistons

a. Wash pistons in solvent to remove grease and oil

(CAUTION: Use a stiff brush, not a wire brush.)

b. Spray the pistons dry using compressed air

c. Clean the pistons in the glass bead cleaning machine using proper size beads and correct pressure

JOB SHEET #1

d. Keep the blast moving

(CAUTION: Do not hold bead blast on one area too long or metal may be eroded.)

e. Hold the nozzle away from the surface; distance will vary depending on recommended pressure

F. Inspect pistons

1. Examine for score marks, damaged ring grooves, or sign of overheating

2. Inspect piston for cracks in head and skirt area and for bent or broken lands

(NOTE: Replace if damaged.)

G. Measure ring grooves for wear

1. Install a new ring in groove (Figure 1)

2. Insert feeler gauge between upper surface of new ring and the land to check clearance (Figure 1)

FIGURE 1 — Measure Ring Clearance with a Feeler Gauge

3. Check all ring grooves at several points

(NOTE: Follow engine manufacturer's recommendation for wear limits.)

JOB SHEET #1

H. Measure piston for wear

1. Using outside micrometers, measure diameter of piston skirt at right angles to the piston pin bore (Figure 2)

FIGURE 2 Checking Piston Wear

2. Take a reading at both top and bottom of the skirt

3. Compare these measurements with new dimensions given in the engine technical manual

4. Note the difference which is piston wear

I. Measure piston to cylinder clearance

1. Measure the cylinder diameter at right angles to the crankshaft in the lower or least-worn area of the cylinder, using a cylinder dial gauge, an inside micrometer, or a telescope gauge with outside micrometer

2. Measure the diameter of the piston across the thrust faces with an outside micrometer (Figure 2)

(NOTE: The difference between these two measurements is the piston clearance. Replace pistons if their clearance exceeds manufacturer's specifications.)

JOB SHEET #1

J. Install rings

1. Using ring expander, install oil control ring (Figure 3)

2. Using ring expander, install compression rings top side up

(NOTE: Refer to engine technical manual for directions on installing different ring types.)

FIGURE 3 – Installing Piston Rings
Using a Ring Expander

3. Stagger the ring ends according to manufacturer's recommendations

(CAUTION: Do not twist, expand, or stretch rings too much.)

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT II

JOB SHEET #2--SERVICE PISTON PIN AND CONNECTING ROD

I. Tools and materials

A. Piston pin vise

B. Straight edge

C. Brass hammer

D. Shop towels

E. Compressed air supply

F. Eye protection

II. Procedure

A. Service piston pin

1. Check pin for out-of-round or looseness

a. Clamp pin in pin vise

b. Rotate rod back and forth on pin

c. Remove rod and examine shiny contact spots

(NOTE: If pin contact does not show over entire surface renew bushing.)

2. Check bore for taper or bellmouthing (Figure 1)

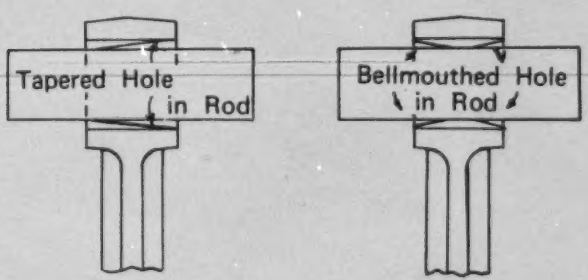


FIGURE 1 – Bad Pin Fits in Connecting Rod

JOB SHEET #2

a. Insert pin from each end of the bushing

(NOTE: If pin is free on one end and tight on opposite end, the pin hole is tapered. If pin enters easily from either end but tight in the center, the pin hole is bellmouthed.)

b. Renew bushing if pin hole is tapered or bellmouthed

3. Check for misalignment between the piston pin holes (Figure 2)

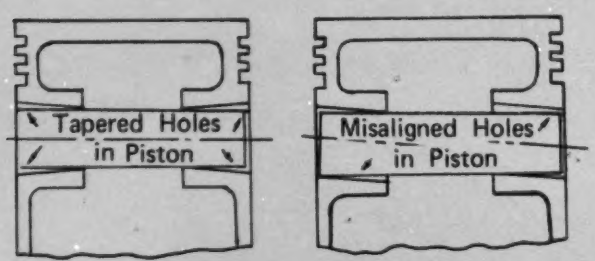


FIGURE 2 – Bad Pin Fits in Piston Bosses

a. Push pin through pin hole toward second piston boss

(NOTE: If pin does not enter second boss without a click, misalignment has occurred.)

b. Install new bushings

JOB SHEET #2

B. Service connecting rods

1. Replace bent or twisted rod if wear points show on bearing in eye or cap (Figure 3)

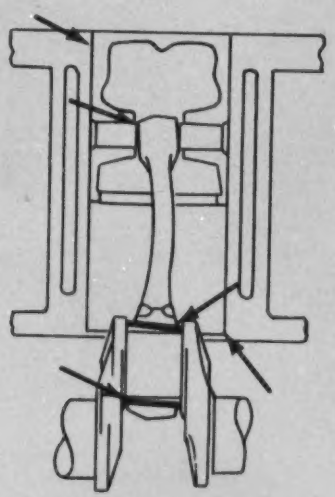


FIGURE 3 – Wear Points from a Bent Rod

2. Replace rod if out of alignment to limit of 0.001 inch in six inches (Figure 4)

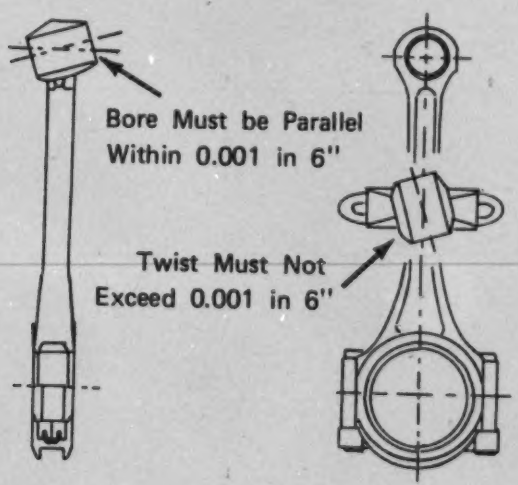


FIGURE 4 – Recommended Limits for Rod Alignment

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT II

JOB SHEET #3--INSTALL PRECISION-INSERT CONNECTING ROD BEARINGS

I. Tools and materials

A. Outside micrometers

B. Inside micrometers

C. Rawhide mallet

D. Torque wrench

E. Oil pan gasket

F. Shop towels

II. Procedure

A. Clean crankpins

B. Visually check for gouges, scratches, grooves, and scored surfaces

C. Measure crankpins in several places with outside micrometers (Figure 1)

(NOTE: Write down minimum and maximum diameters; write down maximum shaft diameters and cylinder location.)

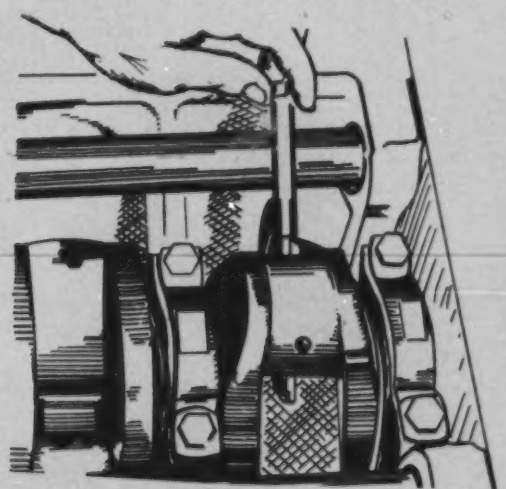


FIGURE 1 – Measuring Crankshaft Rod Journals

JOB SHEET #3

D. Assemble No. 1 cap and rod without bearings (insert shims if provided) and tighten bolts lightly

(NOTE: Tap cap lightly with rawhide mallet just before final tightening to the torque wrench setting recommended.)

E. Check rod bore with inside micrometers or dial bore gauge for out-of-round (Figures 2 and 3)

FIGURE 2

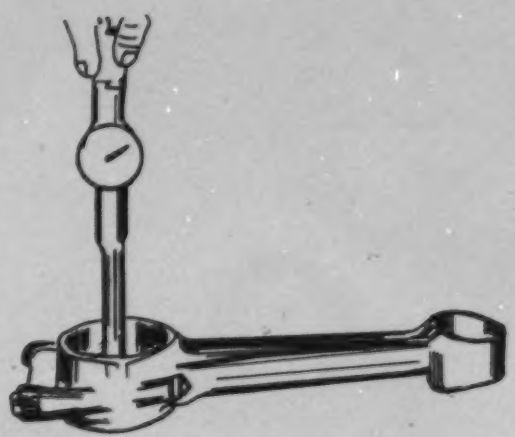


FIGURE 3 – Checking Connecting Rod Crank Journal Bore

F. Remove caps from rods and clean all parts

G. Obtain new bearings to give the correct oil clearance with the maximum shaft sizes previously recorded in C above

(NOTE: Bearing clearance can also be measured with the crankshaft in place by using a plastigage. While this method will give the bearing clearance it will not tell whether the wear is on the bearing or on the crankshaft journal.)

H. Compare old and new bearings for correct oil grooves, holes, and lips

I. Insert correct lower half bearings into caps; make sure lip nests into slot

J. Place No. 1 rod assembly in No. 1 cylinder with marking in correct relation to camshaft; do the same with other rods

K. Insert upper half bearings into rod halves (now in engine); smear engine oil on bearing surfaces

JOB SHEET #3

L. Seat rod with bearing in place upon its crankpin and check rod marking with camshaft position

(CAUTION: See that the rod bolts do not touch crankpin.)

M. Assemble No. 1 cap and rod; do the same with rods No. 2, No. 3, until complete

(NOTE: Markings must be on the same side, with shims inserted, if used in original assembly. See Figures 5 and 6.)

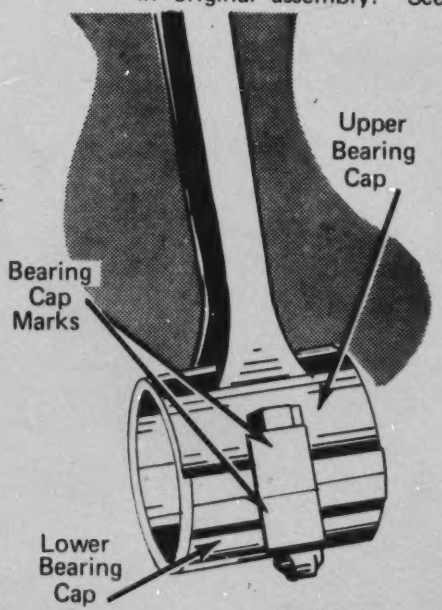


FIGURE 5

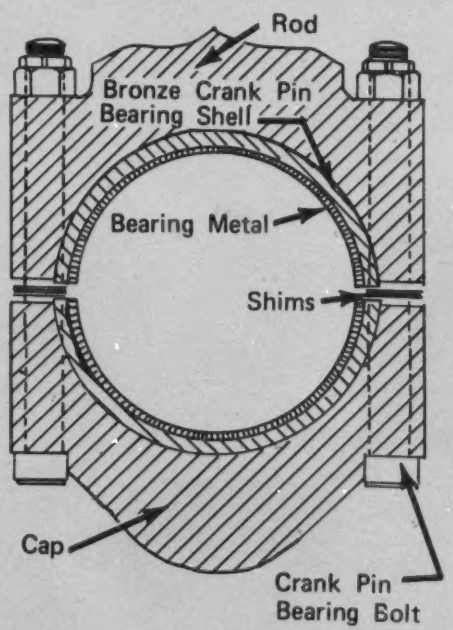


FIGURE 6

N. Take up on bolts lightly

(NOTE: Tap cap with mallet to find natural center.)

O. Tighten with torque wrench to recommended setting

(NOTE: Rotate crankshaft by hand, after tightening each rod, to make sure it does not bind.)

P. Check complete installation in this order: markings, torque wrench readings, crankshaft tightness, and apply cotter pins or lock nuts

Q. Attach oil leak detector, if available, as final check on both main and connecting rod bearings

JOB SHEET #3

R. Clean oil pan and oil pump screen thoroughly

S. Replace oil pan gaskets and assemble to engine

T. Fill with a good grade of oil of recommended viscosity to suit the season

U. Replace oil filter cartridge

V. Clean air cleaner

W. Start engine and run just above idling speed until oil gauge registers normal pressure

X. Initial break-in of the engine bearings should be the same as breaking in a new engine

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT II

NAME_____

TEST

1. Match the terms on the right to the correct definitions.

_____a. Outside part of piston below ring grooves

_____b. Area between ring grooves

_____c. Ties piston and rod together

_____d. Hole in piston which supports piston pin

_____e. Clearance between ends of piston rings

_____f. Combustion gases escaping to the crankcase

_____g. Overloading, causing unusual stress

_____h. Glowing or burning

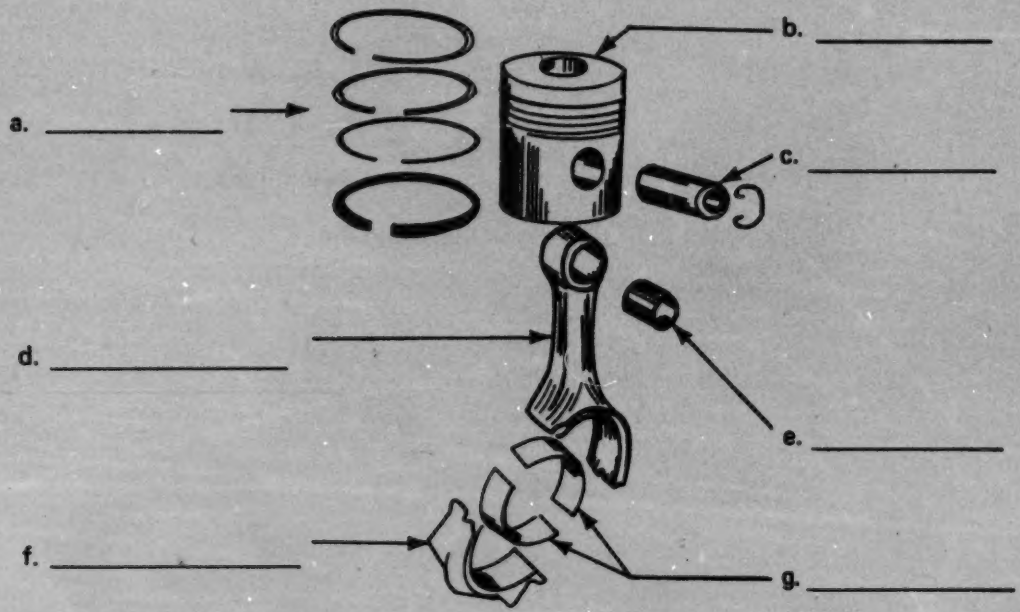
_____i. Upsetting the metal to decrease the inside diameter or increase the outside diameter

_____j. Piston pin that moves in both rod and piston

_____k. Soft, oil soluble, plastic thread

1. Piston pin
2. Piston pin boss
3. Piston land
4. Piston skirt
5. Ring joints
6. Blow-by
7. Plastigage
8. Full floating pin
9. Lugging
10. Incandescent
11. Knurling

2. Identify seven primary parts of a piston and connecting rod assembly.



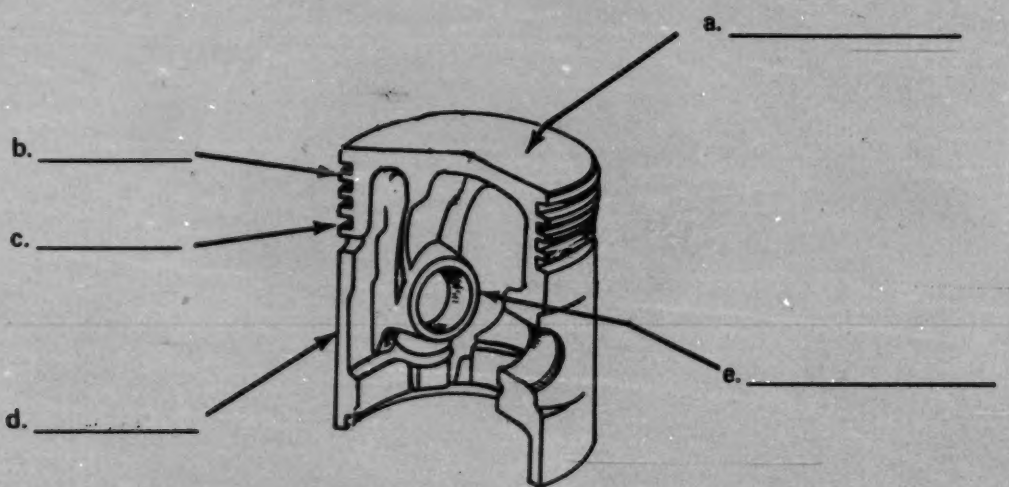
3. List three functions of the piston.

a.

b.

c.

4. Identify five main parts of a piston.



5. List three functions of piston rings.

   a.

   b.

   c.

6. Name the two types of piston rings.

   a.

   b.

7. Name three common types of ring joints.

   a.

   b.

   c.

8. Select possible causes of high oil consumption and blow-by by placing an "X" in the appropriate blanks.

   _____a. Piston rings installed wrong

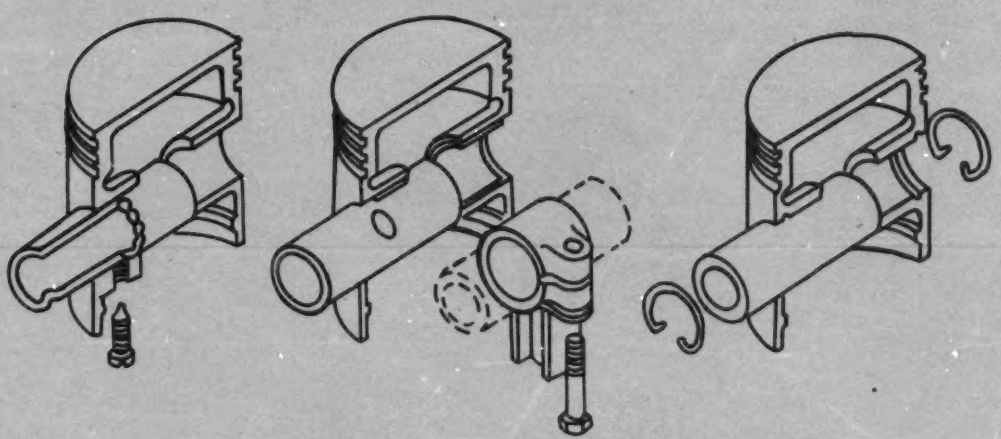
   _____b. Plugged oil ring

   _____c. Stuck oil ring

   _____d. Burned exhaust valve

   _____e. Overall wear in piston, rings, and cylinder

9. Identify three types of piston pins.



a. _____ b. _____ c. _____

10. Name two types of construction for the cap end of a connecting rod.

    a.

    b.

11. Discuss the reason for markings on the connecting rod, piston, and bearing cap.

12. Demonstrate the ability to:

    a. Service piston and install piston rings.

    b. Service piston pin and connecting rod.

    c. Install precision-insert connecting rod bearings.

    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT II

ANSWERS TO TEST

1. a. 4 e. 5 i. 11
   b. 3 f. 6 j. 8
   c. 1 g. 9 k. 7
   d. 2 h. 10

2. a. Piston rings
   b. Piston
   c. Piston pin
   d. Connecting rod
   e. Piston pin bushing
   f. Connecting rod cap
   g. Bearing shells

3. a. Receives the force of combustion
   b. Transmits this force to the crankshaft
   c. Carries the piston rings which seal and wipe the cylinder

4. a. Head or crown
   b. Lands
   c. Ring grooves
   d. Skirt
   e. Piston pin boss

5. a. Forms a gas tight seal between piston and cylinder
   b. Helps cool the piston by transferring heat
   c. Controls lubrication between piston and cylinder wall

6. a. Compression rings

   b. Oil control rings

7. a. Step

   b. Angle

   c. Butt

8. a, b, c, e

9. a. Fixed

   b. Semi-floating

   c. Full floating

10. a. Square cut

    b. Angle cut

11. Discussion should include:

    a. On the piston--To install in same cylinder and on same side from which removed

    b. On the connecting rod--To install in same cylinder and on same side from which removed

    c. On the bearing cap--To install on same rod and on same side from which removed

12. Performance skills evaluated to the satisfaction of the instructor

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify primary parts of a camshaft and parts in a valve train. The student should also be able to explain valve timing on a two-cycle and four-cycle engine and name the gears which are marked in the gear train to insure correct valve timing. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with camshafts and gears to the correct definitions.
2. Name parts on some diesel engines that are actuated by the camshaft.
3. Identify three primary parts of a camshaft.
4. Identify four parts in a valve train.
5. Explain valve timing on a four-cycle engine.
6. Explain valve timing on a two-cycle engine.
7. Name four gears found in a typical gear train.
8. Name three gears which are marked in the gear train to insure correct valve timing.
9. Demonstrate the ability to:
   a. Remove, service, and install a camshaft.
   b. Adjust valve clearance on a valve-in-head engine.

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT III

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined in the job sheets.

G. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete job sheets.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Valve Clearance
2. TM 2--Parts of a Camshaft
3. TM 3--Valve Train
4. TM 4--Gears in a Typical Gear Train
5. TM 5--Timing Marks on Gear Train

D. Job sheets

1. Job Sheet #1--Remove, Service, and Install a Camshaft

2. Job Sheet #2--Adjust Valve Clearance on a Valve-in-Head Engine

E. Test

F. Answers to test

II. References:

A. *Fundamentals of Service: Engines.* Moline, Illinois: Deere and Company, 1972.

B. *Cummins Engine Company Shop Manual.* Columbus, Indiana: Cummins Engine Company, Inc., 1974.

C. *Engine Service Manual.* Peoria, Illinois: Caterpillar Tractor Company, 1972.

D. *Detroit Diesel Engines: Service Manual.* General Motors Corp., 1972.

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT III

INFORMATION SHEET

I. Terms and definitions

A. Cam lobes--Eccentric on the camshaft which changes rotary motion to linear motion

B. Backlash--Clearance between meshed gears

C. Dual valves--Two valves operated by a single rocker arm

D. Bridge or crosshead--Permits a single rocker arm to depress dual valves

E. Valve clearance--Definite clearance between rocker arm and valve stem (Transparency 1)

F. Cam followers--Drive the push rods to operate the valves

(NOTE: Cam followers may also be called valve tappets.)

G. Hydraulic valve lifters--Noiseless cam followers that automatically adjust for valve clearance

II. Parts actuated by the camshaft on some diesel engines

A. Intake valve

B. Exhaust valve

C. Unit injector

D. Air starting valves

III. Primary parts of a camshaft (Transparency 2)

A. Drive gear

B. Cams

C. Bearing journal

IV. Parts in a valve train (Transparency 3)

A. Valve

B. Rocker arm

INFORMATION SHEET

C. Push rod

D. Cam follower

V. Valve timing on a four-cycle engine

A. Camshaft turns at one-half the speed of crankshaft

B. Each valve is opened and closed once during two revolutions of the crankshaft

VI. Valve timing on a two-cycle engine

A. Camshaft turns at the same speed as crankshaft

B. Exhaust valve is opened and closed once during one revolution of the crankshaft

(NOTE: Intake port in cylinder liner is uncovered by the piston once during one revolution of the crankshaft.)

VII. Gears in a typical gear train (Transparency 4)

A. Camshaft gear

B. Crankshaft gear

C. Idler gear

D. Fuel injection pump and governor drive gear

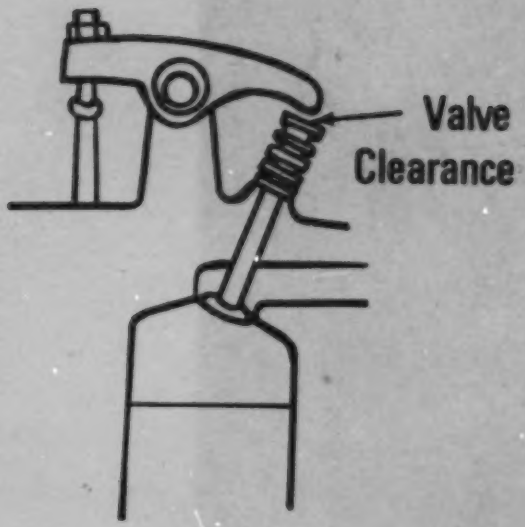
VIII. Gears marked to insure correct valve timing (Transparency 5)

A. Crankshaft gear teeth

B. Idler gear teeth

C. Camshaft gear teeth

Valve Clearance

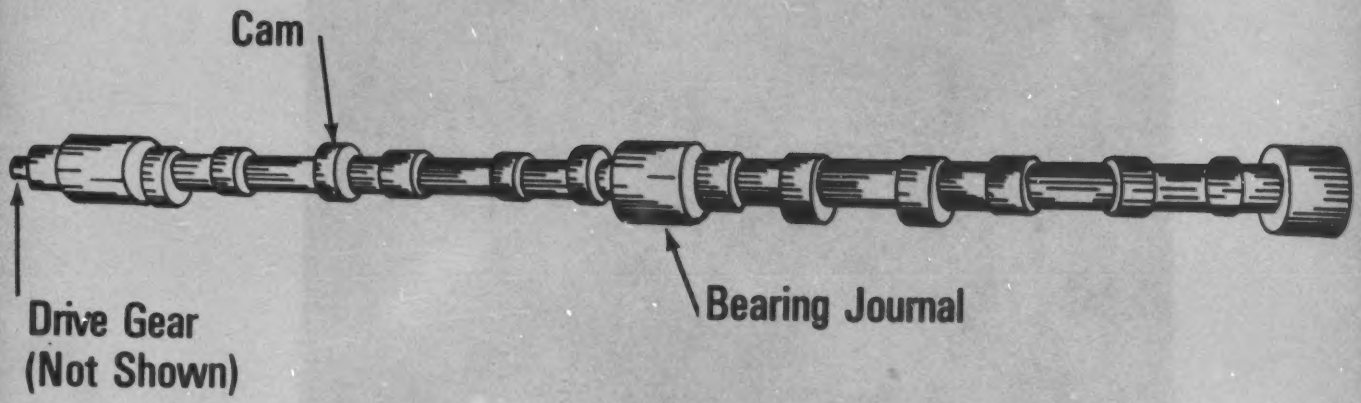


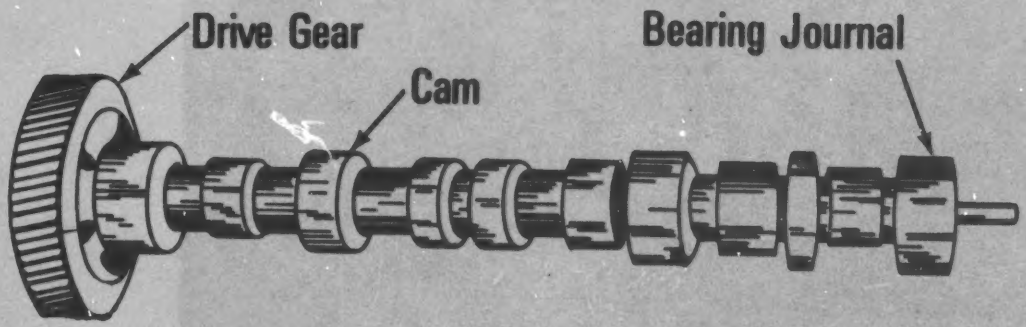
Valve Closes and Seals
Gases in Cylinder

Valve Doesn't Seat.
Power is Lost and Valve
Overheats.

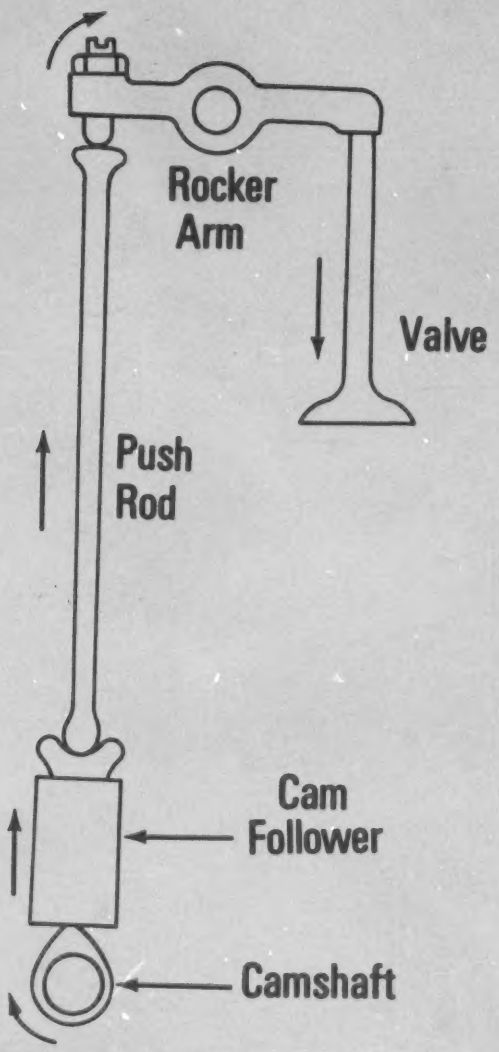
Problem of Too Little Valve Clearance

Parts of a Camshaft

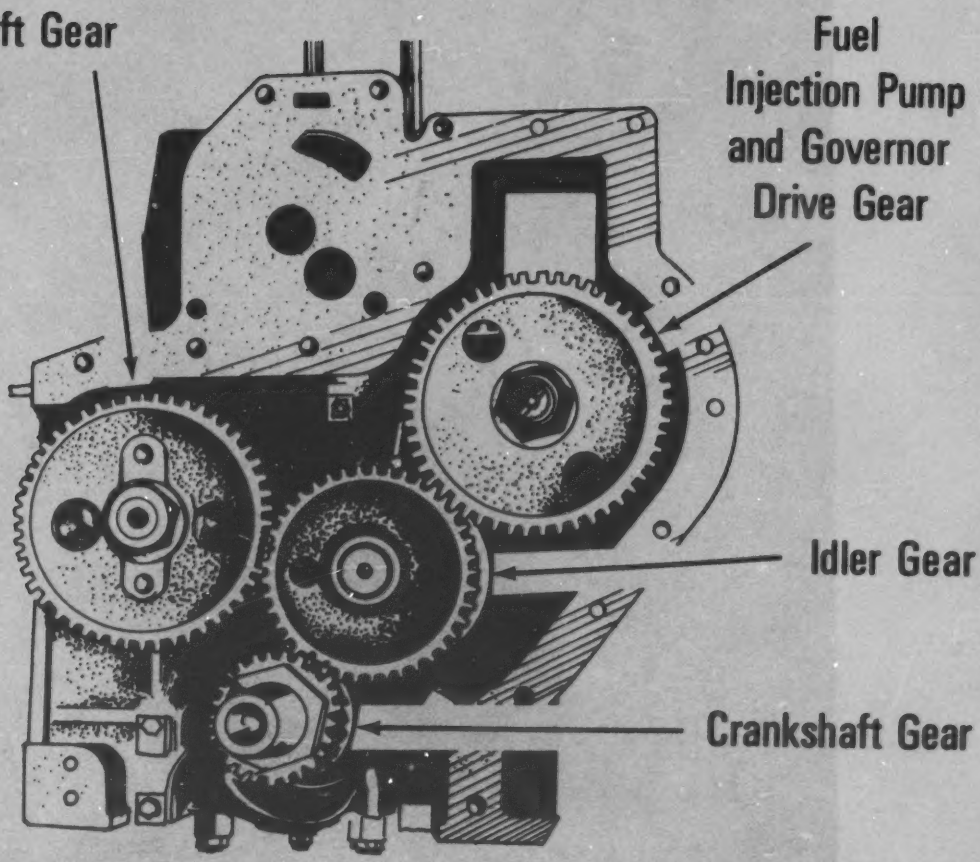




Valve Train
(Valve – in – Head Engine)

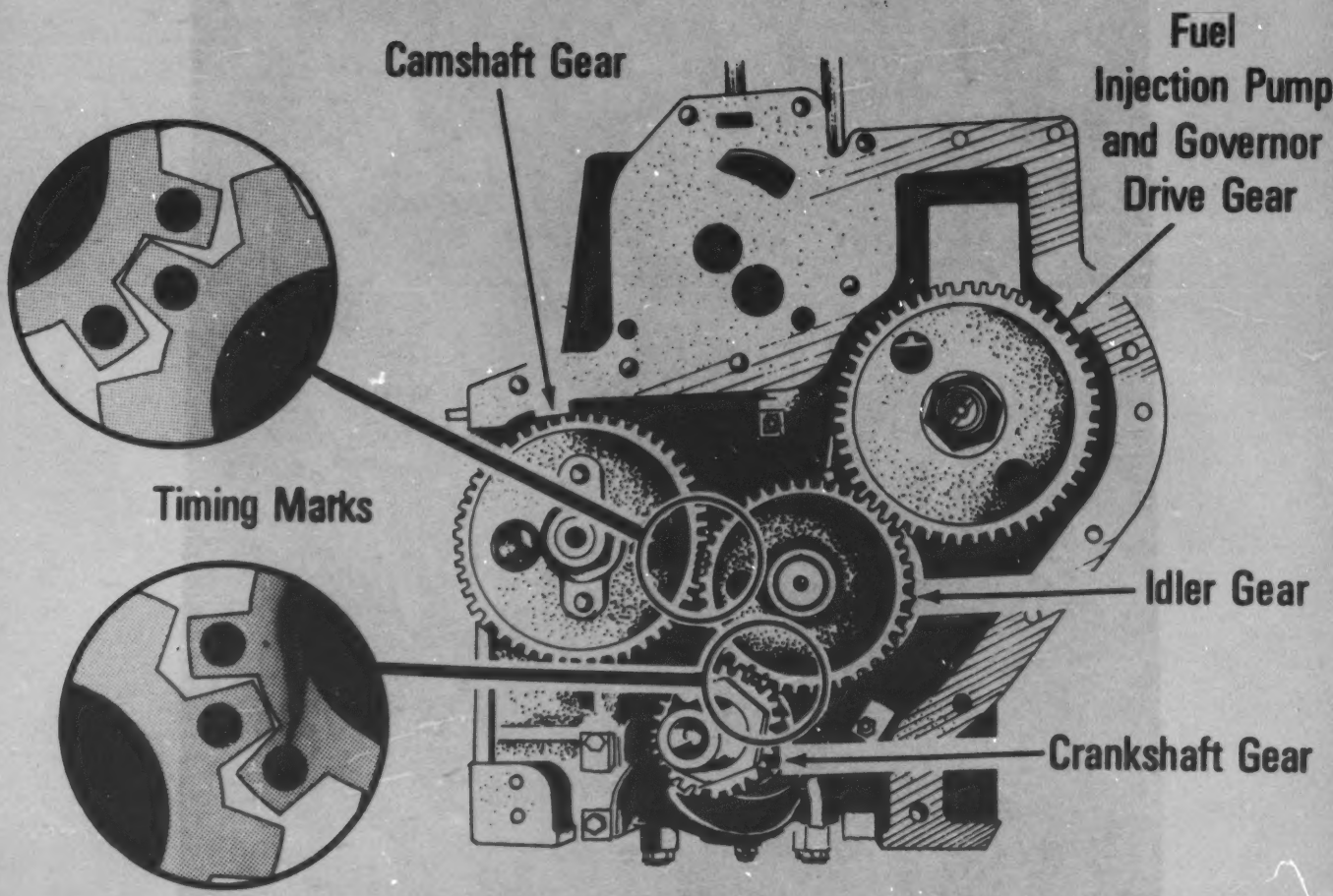


Gears in a Typical Gear Train



Timing Gears

Timing Marks on Gear Train



CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT III

JOB SHEET #1--REMOVE, SERVICE, AND INSTALL CAMSHAFT

I. Tools and materials

A. Outside micrometer

B. Inside micrometer or telescope gauge

C. Shop towels

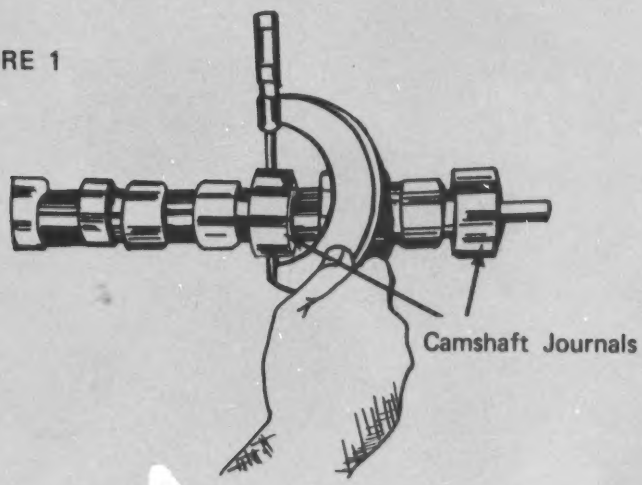
D. Appropriate manufacturer's service manual

II. Procedure

A. Inspect camshaft journals for signs of wear or out-of-round condition

B. Measure the camshaft journals with an outside micrometer (Figure 1)

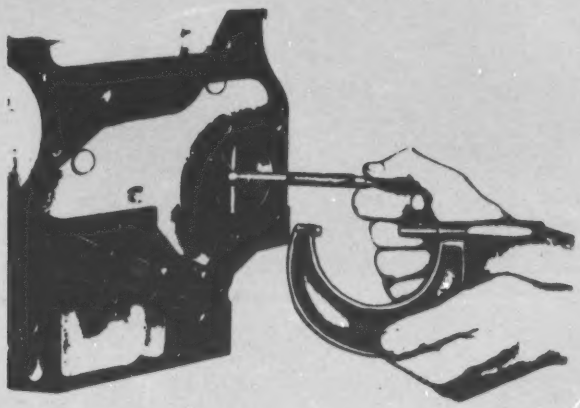
FIGURE 1



JOB SHEET #1

C. Measure the camshaft bores or bearings with a telescope gauge and outside micrometer (Figure 2)

FIGURE 2



Measuring Camshaft Bores

D. Compare the results with specifications given by the manufacturer

E. Using micrometer check each cam lobe for height

F. Compare intakes to other intakes

G. Compare exhausts to other exhausts

H. Replace camshaft if manufacturer's specifications are not met

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT III

JOB SHEET #2--ADJUST VALVE CLEARANCE
ON A VALVE-IN-HEAD ENGINE

I. Tools and materials

A. Correct size end wrench

B. Screwdriver

C. Feeler gauge

D. Shop towel

E. New valve cover gasket

II. Procedure

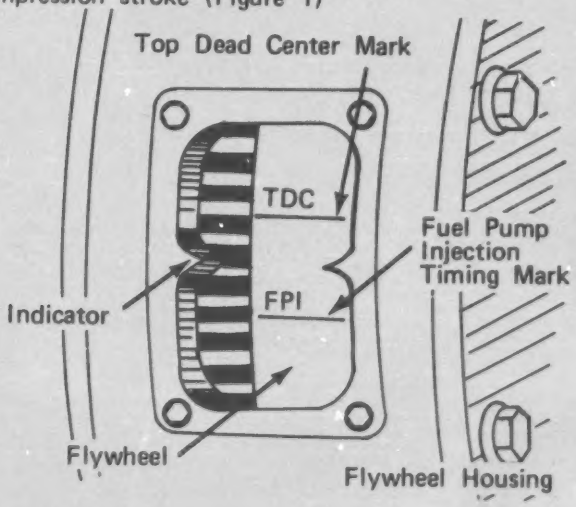
A. Start engine and bring to normal operating temperature

(NOTE: See manufacturer's recommendation for hot or cold adjustment.)

B. Clean all dirt and oil from around valve cover and remove

C. Turn engine over until piston in No. 1 cylinder is at top dead center on the compression stroke (Figure 1)

FIGURE 1



(NOTE: During the compression stroke, both valves must be closed and the push rods must be loose.)

JOB SHEET #2

D. Using a feeler gauge, check the valve clearance (Figure 2)

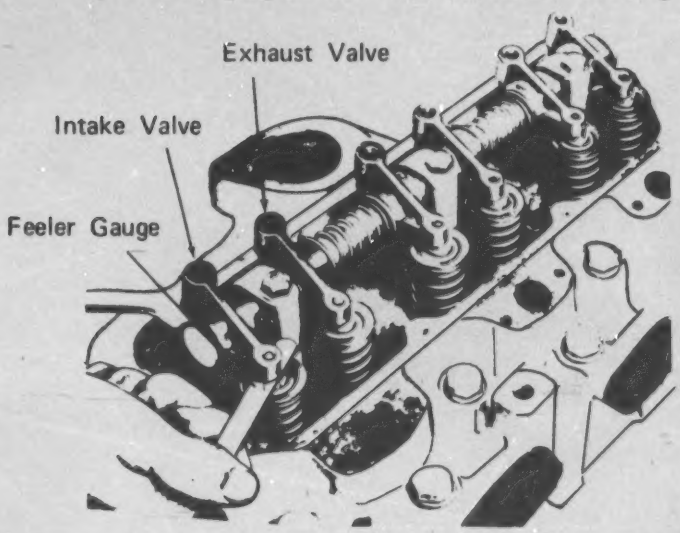


FIGURE 2

(NOTE: Distinguish between the intake and the exhaust valve because the clearance may be different.)

E. Adjust to manufacturer's recommendation by loosening lock nut and turning valve adjusting screw up or down with screwdriver

F. Tighten lock nut with end wrench

G. Rotate the engine crankshaft in its firing order and adjust valve clearance when each piston reaches T.D.C. of its compression stroke

(NOTE: Two or three sets of valves may be set at a time with one rotation of the crankshaft.)

H. Install valve cover, using a new gasket

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT III

NAME_____

TEST

1. Match the terms on the right to the correct definitions.

_____a.	Eccentric on the camshaft which changes rotary motion to linear motion	1.	Bridge or crosshead
_____b.	Clearance between meshed gears	2.	Dual valves
_____c.	Two valves operated by a single rocker arm	3.	Cam lobes
_____d.	Drive the push rods to operate the valves	4.	Backlash
_____e.	Noiseless cam followers that automatically adjust for valve clearance	5.	Cam followers
_____f.	Definite clearance between rocker arm and valve stem	6.	Hydraulic valve lifters
_____g.	Permits a single rocker arm to depress dual valves	7.	Valve clearance

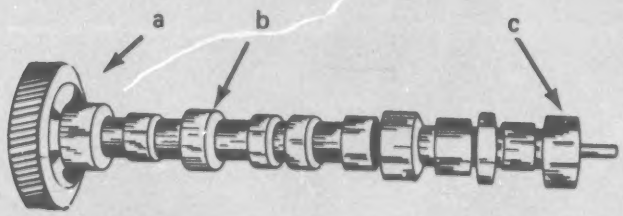
2. Name three parts on some diesel engines that are actuated by the camshaft.

a.

b.

c.

3. Identify three primary parts of a camshaft.

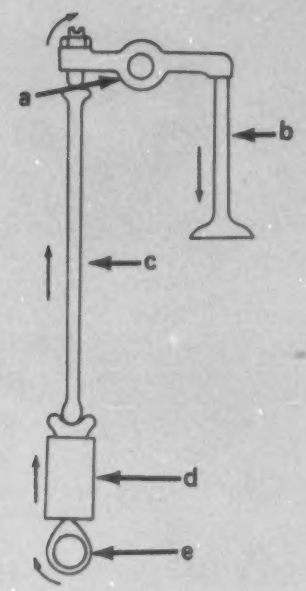


a.

b.

c.

4. Identify four parts in a valve train.



a.

b.

c.

d.

5. Explain valve timing on a four-cycle engine.

6. Explain valve timing on a two-cycle engine.

7. Name four gears found in a typical gear train.

a.

b.

c.

d.

8. Name three gears which are marked in the gear train to insure correct valve timing.

   a.

   b.

   c.

9. Demonstrate the ability to:

   a. Remove, service, and install a camshaft.

   b. Adjust valve clearance on a valve-in-head engine.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT III

ANSWERS TO TEST

1. a. 3
   b. 4
   c. 2
   d. 5
   e. 6
   f. 7
   g. 1
2. Any three of the following:
   a. Intake valve
   b. Exhaust valve
   c. Unit injector
   d. Air starting valves
3. a. Drive gear
   b. Cams
   c. Bearing journal
4. a. Rocker arm
   b. Valve
   c. Push rod
   d. Cam follower.
5. Explanation should include:
   a. Camshaft turns at one-half the speed of crankshaft
   b. Each valve is opened and closed once during two revolutions of the crankshaft
6. Explanation should include:
   a. Camshaft turns at the same speed as crankshaft
   b. Exhaust valve is opened and closed once during one revolution of the crankshaft

7. a. Camshaft gear
   b. Crankshaft gear
   c. Idler gear
   d. Fuel injection pump and governor drive gear
8. a. Crankshaft gear teeth
   b. Idler gear teeth
   c. Camshaft gear teeth
9. Performance skills evaluated to the satisfaction of the instructor

FRAMES AND CYLINDER BLOCKS
UNIT IV

UNIT OBJECTIVE

After completion of this unit, the student should be able to name the stationary parts of three typical frame designs. The student should also be able to name three ways cylinder blocks may be constructed in regard to the cylinder proper and match the types of liners to statements on wet and dry liners. He should also be able to inspect, remove, and replace a cylinder liner. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match frame and cylinder block terms with the correct functions.
2. Name the stationary parts of three typical frame designs.
3. Describe the purpose of through-bolts on an A-frame design engine.
4. Name three ways cylinder blocks may be constructed in regard to the cylinder proper.
5. Name two advantages a removable liner has over the integral cylinder bore.
6. Match the types of liners to statements on wet and dry liners.
7. Demonstrate the ability to inspect, remove, and replace a cylinder liner.

FRAMES AND CYLINDER BLOCKS
UNIT IV

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined in the job sheet.

G. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete job sheet.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Engine Frames
2. TM 2--Cylinder Liners
3. TM 3--Cylinder Block and Cylinder Liner

D. Job Sheet #1--Inspect, Remove, and Replace a Cylinder Liner

E. Test

F. Answers to test

II. References:

A. Kates, Edgar J., and Luck, William E. *Diesel and High Compression Gas Engines*. 3rd ed. Chicago: American Technical Society, 1972.

B. *Fundamentals of Service: Engines*. Moline, Illinois: Deere and Company, 1972.

C. *Cummins Engine Company Shop Manual*. Columbus, Indiana: Cummins Engine Company, Inc., 1974.

FRAMES AND CYLINDER BLOCKS
UNIT IV

INFORMATION SHEET

I. Frame and cylinder block terms and functions

A. Frame--Stationary part which supports engine and keeps moving parts in line

B. A-frame--Center frame has shape like an "A" and supports cylinder blocks

C. Bed plate--Supports main bearings

D. Center frame--Carries cylinder liners

E. Through-bolts--Ties the bed plate, center frame, and head together

F. Integral cylinder--Cylinder and water jacket cast in one piece

G. Cylinder liner--Inside surface of the cylinder

H. Wet liner--Liner is inserted into cylinder casting to form water jacket

I. Dry liner--Makes metal to metal contact with cylinder casting containing water jacket

II. Stationary parts of frame designs (Transparency 1)

A. Two-piece frame

1. Bed plate

2. Center frame

(NOTE: For stationary engines which rest on a substantial foundation, the two-piece construction is most widely used.)

B. Three-piece frame

1. Bed plate

2. Center frame

3. Cylinder block

INFORMATION SHEET

C. A-frame

1. Bed plate

2. Center frame

(NOTE: Another frame design is the automotive type, in which case the bearings are underslung from the upper section and the lower section is a crank pan.)

III. A-frame design with through-bolts

A. Bed plate supports frames

B. Frames support cylinder block

C. Cylinder block supports cylinder head

D. Through-bolts tie A, B, and C together

IV. Cylinder block construction (Transparency 2 and 3)

A. Cylinder bore an integral part of block

B. Cylinder bore with removable wet liner

C. Cylinder bore with removable dry liner

V. Advantages of removable liners over integral cylinder bore

A. Allows room for expansion lengthwise

B. May be replaced separately when worn

VI. Wet and dry liners (Transparency 2 and 3)

A. Wet liners

1. Provide better cooling of cylinder

2. May be replaced separately when worn

B. Dry liners

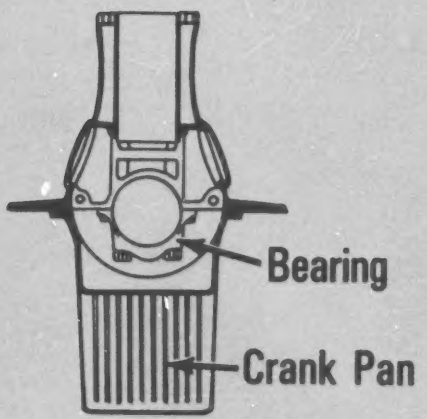
1. Less trouble to replace

2. Less expensive

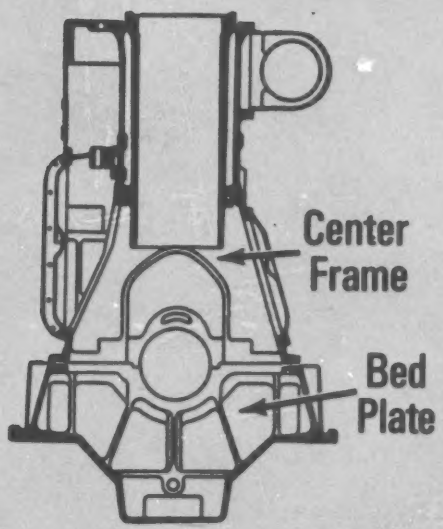
3. Allow room for expansion lengthwise

4. May be replaced separately when worn

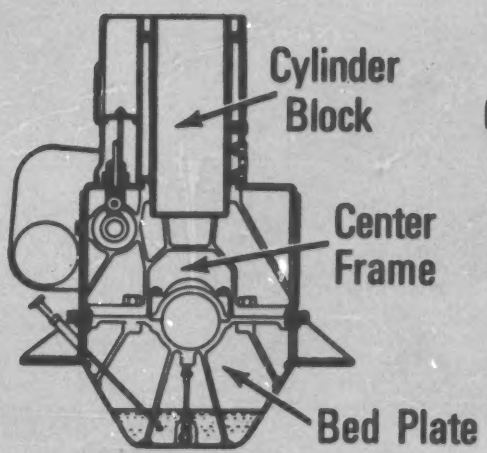
Engine Frames



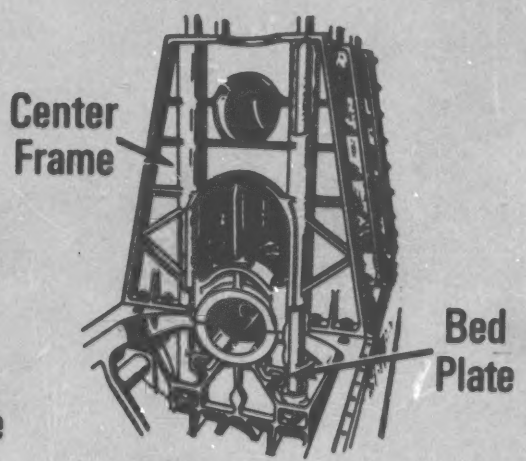
Automotive-Type Frame



Two-Piece Frame

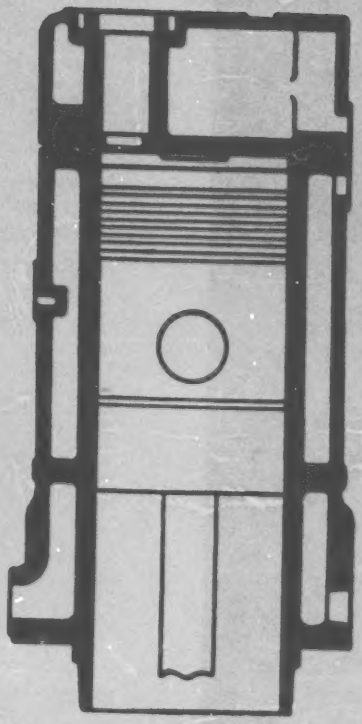


Three-Piece Frame



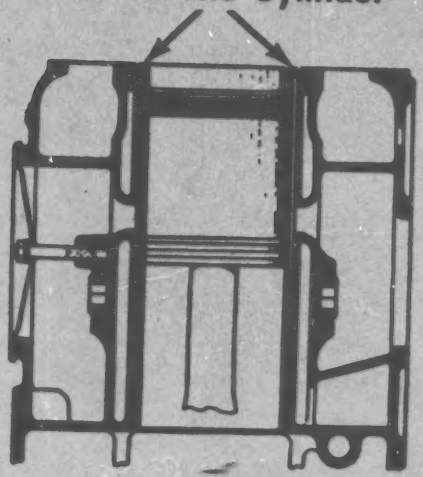
A-Frame Construction

Cylinder Liners



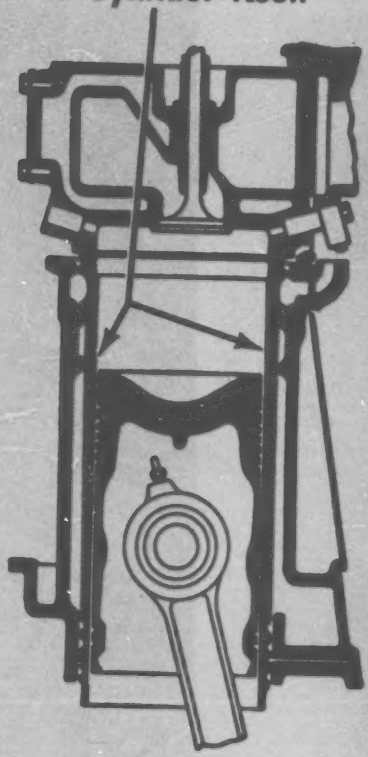
Cylinder Cast as One Piece

Liner is A Sleeve
Inside The Cylinder



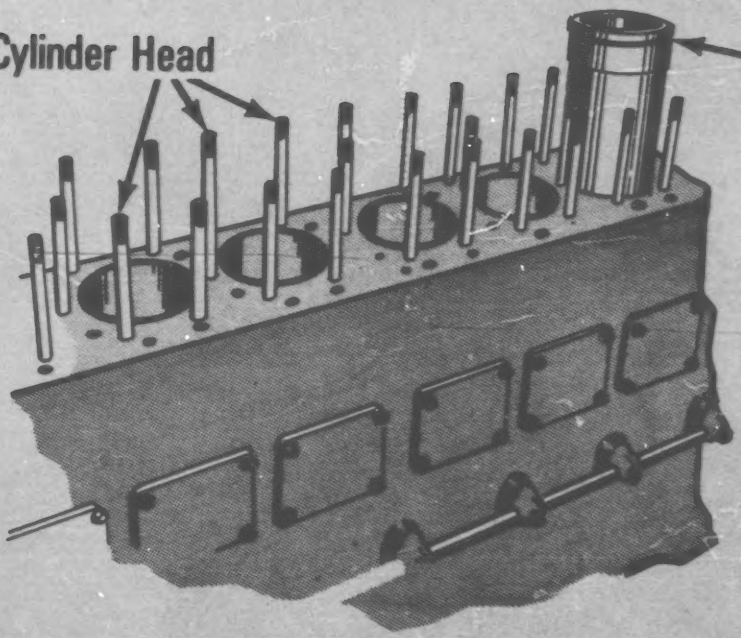
Dry Cylinder Liner

Liner Forms
The Cylinder Itself



Wet Cylinder Liner

Cylinder Block and Cylinder Liner



FRAMES AND CYLINDER BLOCKS
UNIT IV

JOB SHEET #1--INSPECT, REMOVE, AND REPLACE A CYLINDER LINER

I. Tools and materials

A. Cylinder gauge with dial indicator or inside micrometers

B. Screw type pulling tool or liner removing tool

C. New sealing rings

D. Compressed air supply

E. Manufacturer's specifications on cylinder wear limits

F. Commercial scale remover

G. Grease or soap

H. Wire brush

I. Basic hand tool set

II. Procedure

A. Remove cylinder head, oil pan, and pistons

B. Inspect liner for wear

1. Get a cylinder gauge with a dial indicator

2. Set contacts to original size of bore and turn dial indicator to read zero

3. Press in on contacts and slide gauge into the bore

4. Slide gauge slowly up and down in cylinder then around in cylinder

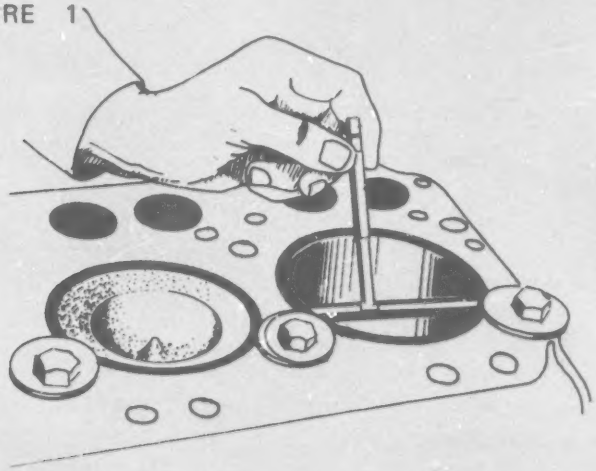
5. Check gauge readings against manufacturer's maximum allowable clearance

JOB SHEET #1

C. Inspect to find taper

1. Measure the bore parallel to the crankshaft at both the top and the bottom (Figure 1)

FIGURE 1



2. Measure at right angle to the crankshaft at both the top and the bottom

3. Compare the top parallel reading with the bottom parallel reading

(NOTE: The difference will be taper for a quarter section.)

4. Compare the top right angle reading to the bottom right angle reading

(NOTE: The difference will be taper 90° from the quarter section.)

D. Inspect to measure out-of-round

1. Measure the bore in a position parallel to crankshaft

2. Measure in a position at right angles to the crankshaft

(NOTE: The difference will show how much out-of-round the cylinder is at that point.)

Example: If the engine bore is 6" and it is more than .015 out-of-round, the liner should be replaced

JOB SHEET #1

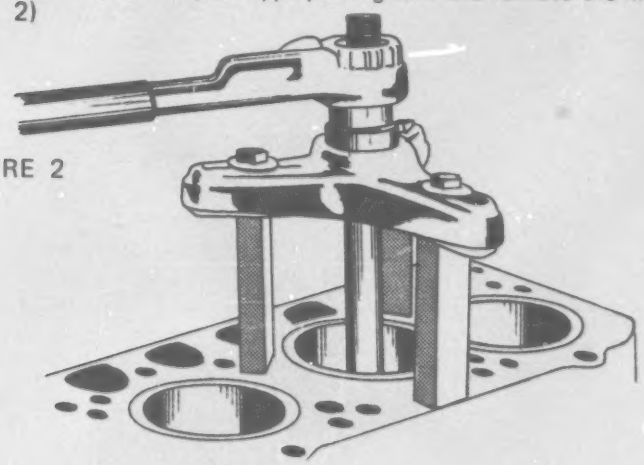
E. Remove liner

1. Record the marking on top of liner and cylinder block

(NOTE: If not marked, make mark before removal.)

2. Use screw or impact type pulling tool and remove the liner (Figure 2)

FIGURE 2



3. Discard all used sealing rings

F. Clean cylinder block bores using steam

G. Dip bores in cleaning solution

H. Clean oil passages using wire brush

I. Blow out with compressed air

J. Clean water passages using commercial scale remover

K. Follow manufacturer's recommended procedures

L. Install new or rebored liner

1. Adjust liner projection in accordance to manufacturer's specifications

2. Place new sealing rings in correct grooves

3. Coat entire outer surface with soap or grease

4. Set liner squarely in cylinder bore and press firmly

5. Pull down with cylinder head stud nuts

FRAMES AND CYLINDER BLOCKS
UNIT IV

NAME_____

TEST

1. Match the terms on the right to the correct functions.

_____a.	Stationary part which supports engine and keeps moving parts in line	1.	Dry liner
_____b.	Center frame has shape like an "A" and supports cylinder blocks	2.	A-frame
_____c.	Supports main bearings	3.	Cylinder liner
_____d.	Carries cylinder liners	4.	Integral cylinder
_____e.	Ties the bed plate, center frame, and head together	5.	Wet liner
_____f.	Cylinder and water jacket cast in one piece	6.	Center frame
_____g.	Inside surface of the cylinder	7.	Bed plate
_____h.	Liner is inserted into cylinder casting to form water jacket	8.	Through-bolts
_____i.	Makes metal to metal contact with cylinder casting containing water jacket	9.	Frame

2. Name the stationary parts of three typical frame designs.

a. Two-piece frame

1)

2)

b. Three-piece frame

1)

2)

3)

c. A-frame

1)

2)

3. Describe the purpose of through-bolts on an A-frame design engine.

4. Name three ways cylinder blocks may be constructed in regard to the cylinder proper.

   a.

   b.

   c.

5. Name two advantages a removable liner has over the integral cylinder bore.

   a.

   b.

6. Match the types of liners on the right to statements on wet and dry liners.

_____a. Less trouble to replace	1. Wet liner
_____b. Less expensive	2. Dry liner
_____c. Provides better cooling of cylinders	
_____d. May be replaced separately when worn	
_____e. Allows room for expansion lengthwise	

7. Demonstrate the ability to inspect, remove, and replace a cylinder liner.

   (NOTE: If this activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

FRAMES AND CYLINDER BLOCKS
UNIT IV

ANSWERS TO TEST

1. a. 9
   b. 2
   c. 7
   d. 6
   e. 8
   f. 4
   g. 3
   h. 5
   i. 1

2. a. Two-piece frame
      1) Bed plate
      2) Center frame
   b. Three-piece frame
      1) Bed plate
      2) Center frame
      3) Cylinder block
   c. A-frame
      1) Bed plate
      2) Center frame

3. Description should include:
   a. Bed plate supports frames
   b. Frames support cylinder block
   c. Cylinder block supports cylinder head
   d. Through-bolts tie a, b, and c together

4. a. Cylinder bore an integral part of block
   b. Cylinder bore with removable wet liner
   c. Cylinder bore with removable dry liner

5. a. Allows room for expansion lengthwise

   b. May be replaced separately when worn

6. a. 2

   b. 2

   c. 1

   d. 1 and 2

   e. 2

7. Performance skills evaluated to the satisfaction of the instructor

CRANKSHAFTS AND BEARINGS
UNIT V

UNIT OBJECTIVE

After completion of this unit, the student should be able to name the parts of a crankshaft and explain how the crankshaft and surrounding parts are lubricated. The students should also be able to list engine indications of bearing failure and disassemble, inspect, and replace crankshaft assembly and engine bearings. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with crankshafts and bearings to the correct definitions.
2. Name four types of crankshaft construction.
3. Name six parts of a crankshaft.
4. List the effects of the arrangement of crankshaft throws.
5. Match the arrangement of crankcase throws to the number of cylinders in the engine.
6. Name three ways crankshaft balance is maintained.
7. Explain the lubrication of the crankshaft and surrounding parts.
8. Distinguish between a bushing and a bearing.
9. Name three materials used in making bearing linings.
10. Name two types of bearing locks.
11. Explain what is meant by bearing crush.
12. State the purpose of oil grooves in the bearing.
13. Name two types of thrust bearings.
14. List three engine indications of bearing failure.
15. Match the percentages of bearing failure to the causes of bearing failure.

16. List functions of the flywheel.

17. Demonstrate the ability to disassemble, inspect, and replace crankshaft assembly and engine bearings.

CRANKSHAFTS AND BEARINGS
UNIT V

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined in the job sheet.

G. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete job sheet.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Parts of the Crankshaft
2. TM 2--Arrangement of Crankshaft Throws
3. TM 3--Counterweights, Vibration Damper, and Flywheel
4. TM 4--Crankshaft Lubrication

5. TM 5--Bushings and Bearings
6. TM 6--Bearing Locks
7. TM 7--Bearing Crush
8. TM 8--Bearing Oil Grooves
9. TM 9--Types of Thrust Bearings
10. TM 10--Causes of Bearing Failure

D. Job Sheet #1--Disassemble, Inspect, and Replace Crankshaft Assembly and Engine Bearings

E. Test

F. Answers to test

II. References:

A. *Engine Bearing Service Manual,* 8th ed. Detroit, Michigan: Federal-Mogul Corp.

B. *Engine Service Manual.* Peoria, Illinois: Caterpillar Tractor Company, 1972.

C. *Cummins Engine Company Shop Manual.* Columbus, Indiana: Cummins Engine Company, Inc., 1974.

D. *Fundamentals of Service: Engines.* Moline, Illinois: Deere and Company, 1972.

CRANKSHAFTS AND BEARINGS
UNIT V

INFORMATION SHEET

I. Terms and definitions (Transparency 1)

A. Integral crankshaft--Made from a single billet of steel

B. Journal--That part of a shaft or axle in contact with the bearing

C. Crankshaft throw--Two crankshaft webs and one crankpin

D. Crankshaft web--Forms the crank or throw between the crankpin and main journal

E. Crankpin--Outer end of crank throw

(NOTE: The crankpin is also called a connecting rod journal.)

F. Vibration damper--Reduces torsional stress on the crankshaft caused by power strokes and the loads on the engine

G. Statically balanced--Balanced while at rest

H. Dynamically balanced--Balanced against the rotary outward force at high speed

I. Bushing--Full round sleeve normally used to support light loads

J. Bearing--Half round sleeve normally used to support heavy loads

K. Bearing clearance--Measured difference between the inside diameter of the bearing and the outside diameter of the journal

L. Short block--Engine block without cylinder head and external accessories

II. Types of crankshaft construction

A. Integral--For small and medium size engines

B. Sectional--For medium and large engines

C. Semi-built-up--For large engines

D. Built-up--For large engines

INFORMATION SHEET

III. Parts of a crankshaft (Transparency 1)

- A. Main bearing journals
- B. Connecting rod bearing journals
- C. Connecting rod counterweights
- D. Flywheel hub or flange
- E. Crankshaft gear
- F. Crankshaft throw

IV. Effects of the arrangement of crankshaft throws (Transparency 2)

- A. Balance the engine
- B. Smooth vibrations of turning shaft
- C. Equalize loads on the main bearings
- D. Determine the firing order of engine

V. Arrangement of crankshaft throws (Transparency 2)

- A. Two and four cylinder, throws 180° apart
- B. Three and six cylinder, throws 120° apart
- C. Eight cylinder, throws 90° apart

VI. Maintaining crankshaft balance (Transparency 3)

- A. Counterweights
- B. Vibration damper
- C. Flywheel

VII. Lubrication of crankshaft and surrounding parts (Transparency 4)

- A. Oil pressure through holes in journals
- B. Oil spray from excess

INFORMATION SHEET

VIII. How bushings and bearings are used (Transparency 5)

A. Bushings--A fully round sleeve used to support light loads and slow speeds

B. Bearings--A half round sleeve used to support heavy loads and high speeds

IX. Materials used in bearing linings

A. Tin or lead base babbit

B. Copper or aluminum alloys

C. Multilayers of copper or aluminum alloys and silver combinations

X. Types of bearing locks (Transparency 6)

A. Lip slot

B. Dowel

XI. Bearing crush--Height of bearing insert above bearing cap to allow for a fully seated bearing when tightened (Transparency 7)

XII. Purpose of bearing oil grooves--Bearing oil grooves carry the oil through to the connecting rod (Transparency 8)

XIII. Types of thrust bearings (Transparency 9)

A. Separate thrust washers

B. Thrust flanges on bearings

XIV. Engine indications of bearing failure

A. Drop in lubricating oil pressure

B. Excessive oil consumption

C. Engine noise--Rythmic knock

XV. Major causes of bearing failure (Transparency 10)

A. Dirt--43 percent

B. Lack of lubrication--16 percent

C. Improper assembly--14 percent

INFORMATION SHEET

D. Misalignment--10 percent

E. Overloading--9 percent

F. Other--8 percent

XVI. Functions of flywheel

A. Stores energy for momentum between power strokes

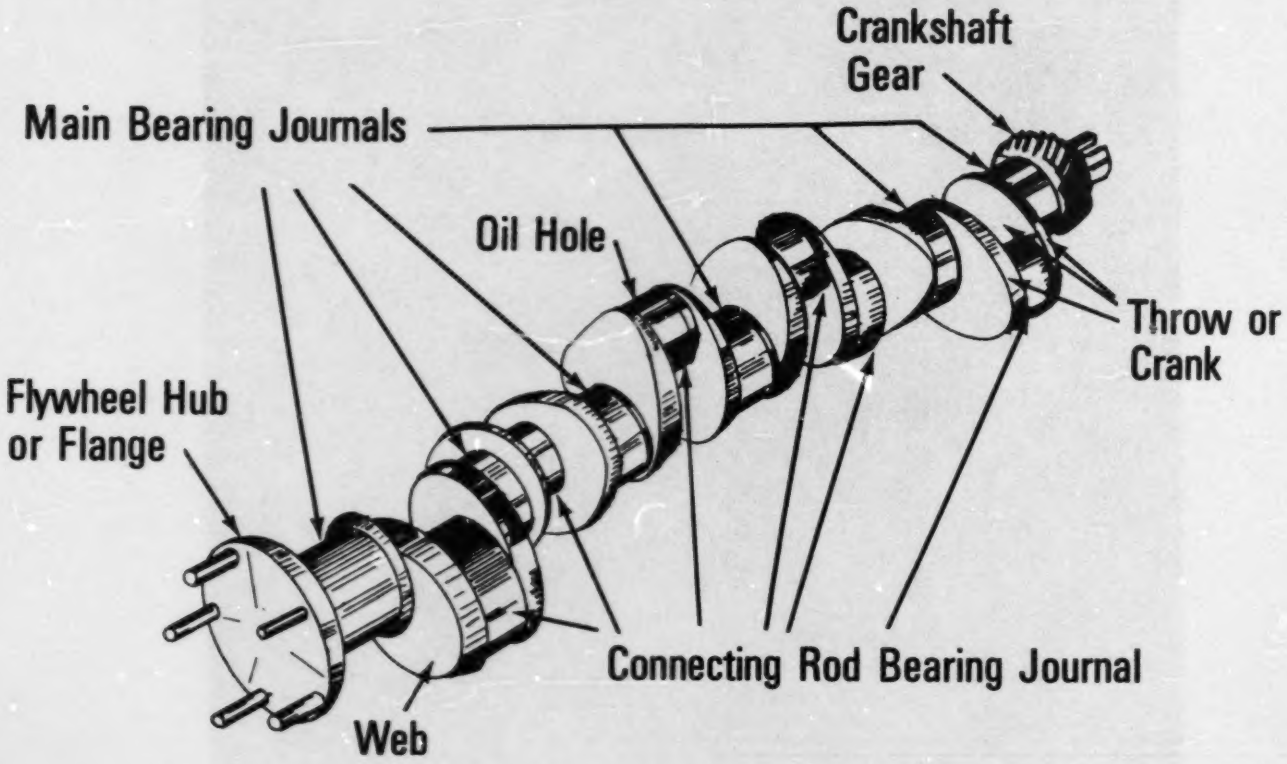
B. Smooths out speed of crankshaft

C. Transmits power to driven machine

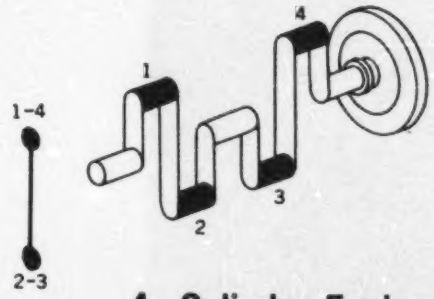
D. Provides a drive for starter via ring gear

E. Serves as a facing for engine clutch

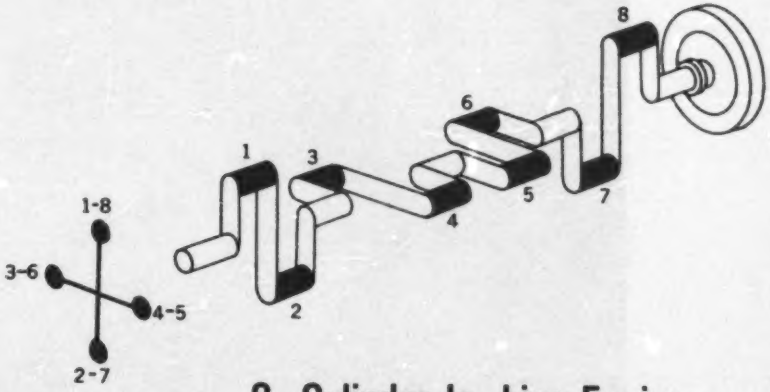
Parts of the Crankshaft



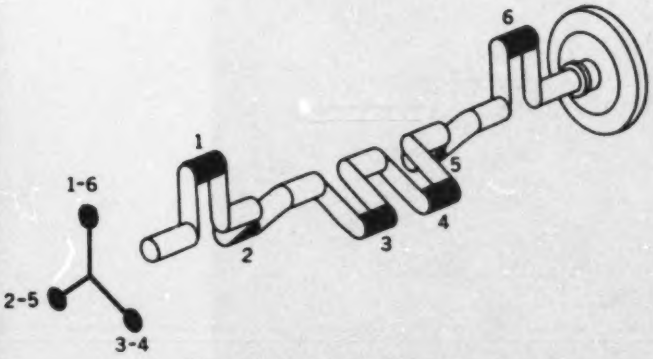
Arrangement of Crankshaft Throws



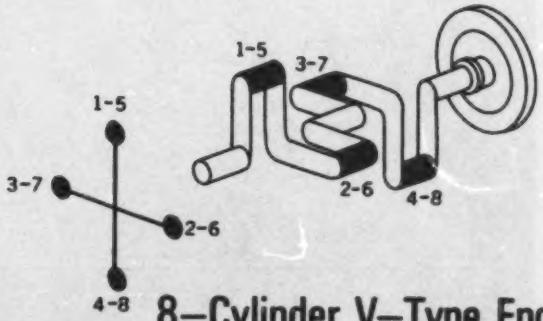
4–Cylinder Engine



8–Cylinder In–Line Engine

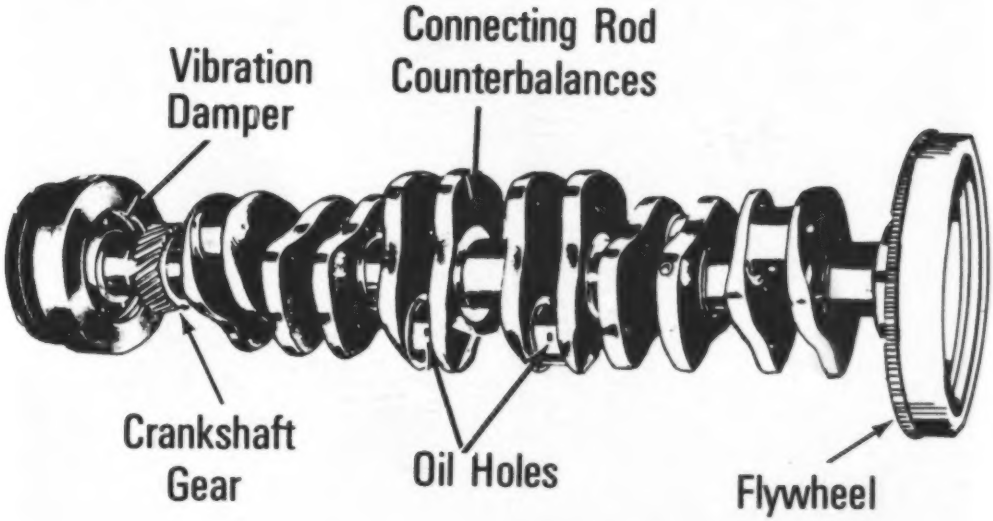


6–Cylinder Engine



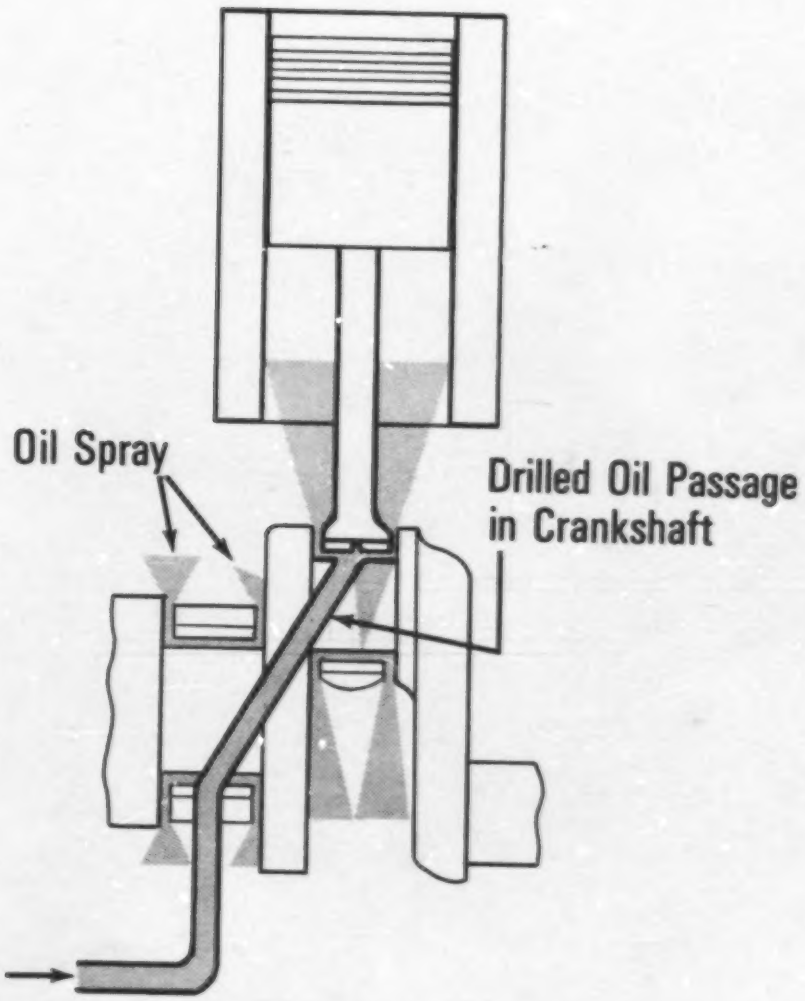
8–Cylinder V–Type Engine

Counterweights, Vibration Damper and Flywheel



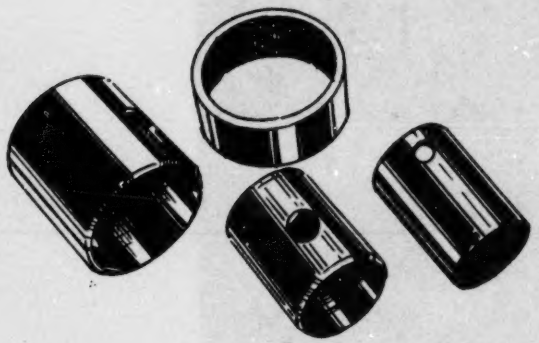
A Six–Cylinder, Seven–Main– Bearing Crankshaft.

Crankshaft Lubrication



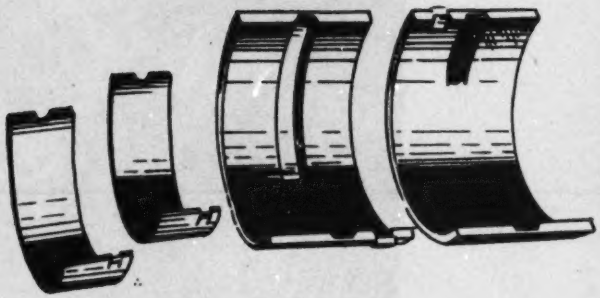
Bushings and Bearings

Bushings



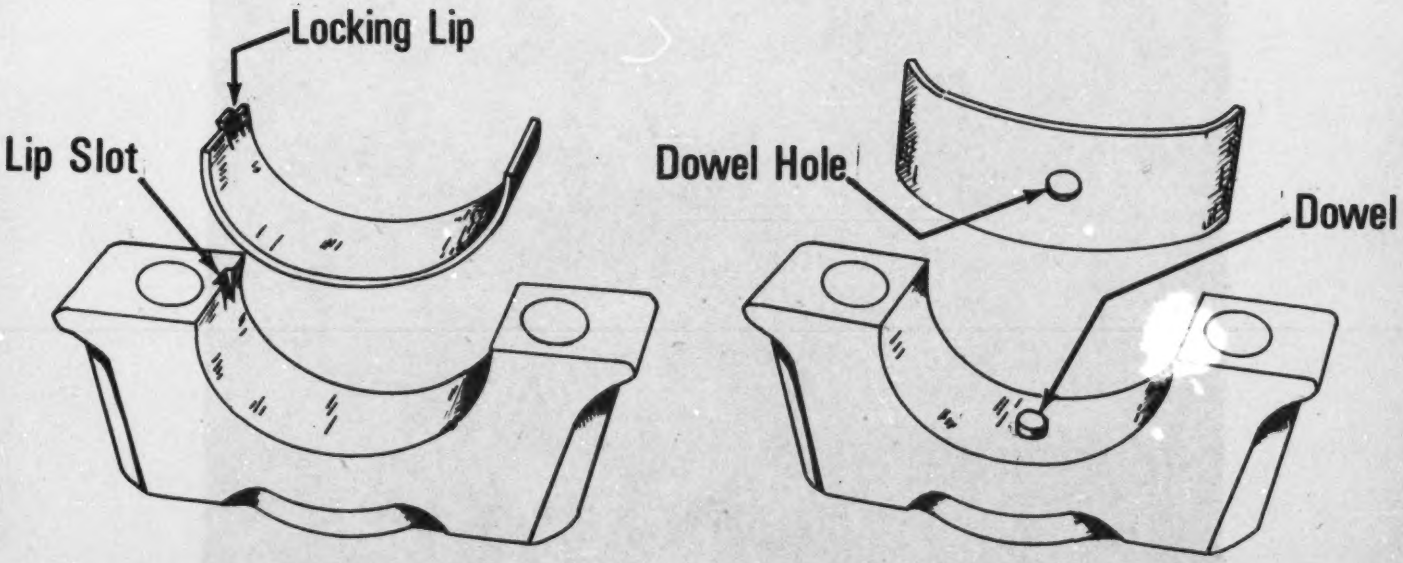
For Light Loads

Bearings

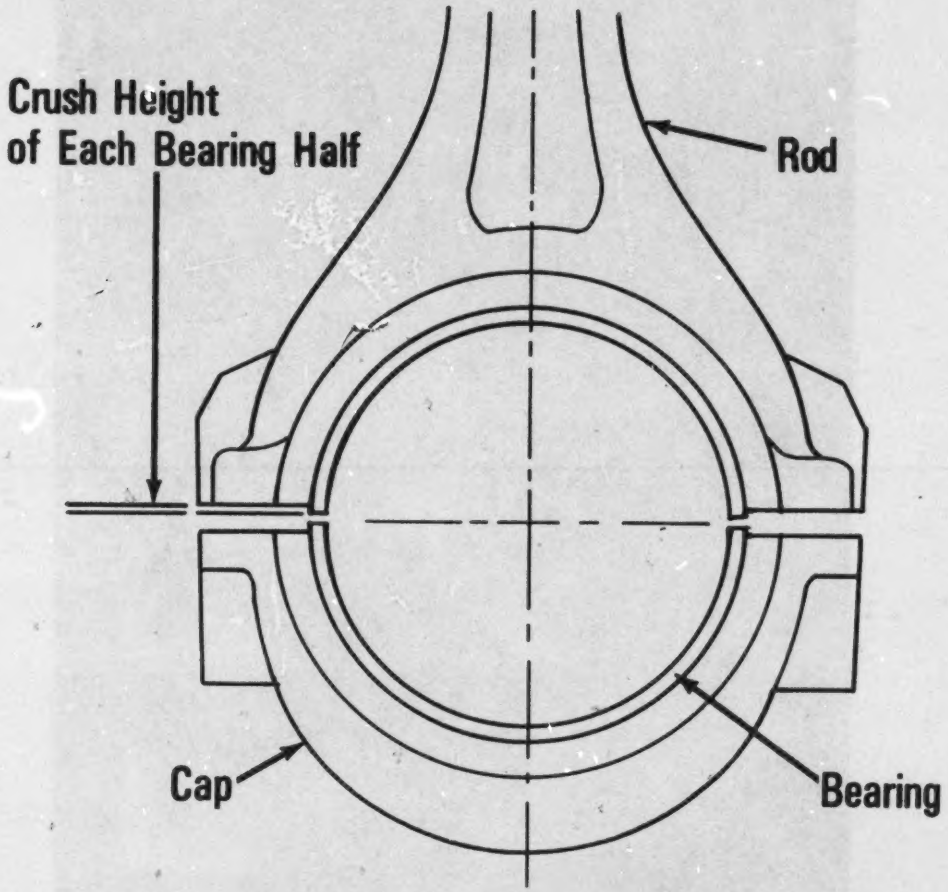


For Heavy Loads

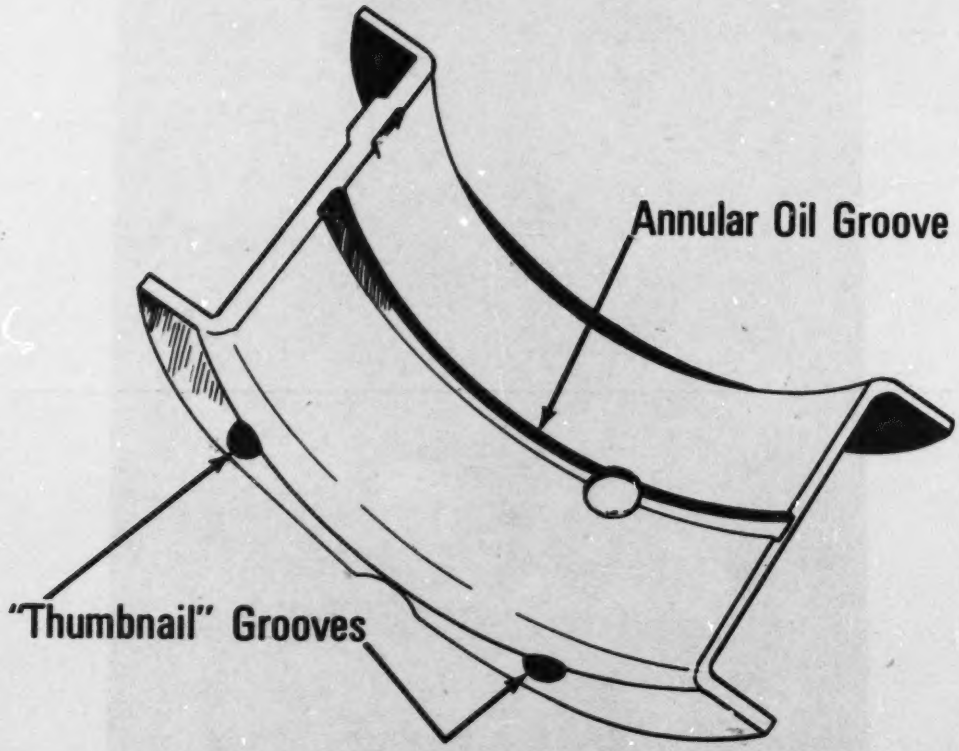
Bearing Locks



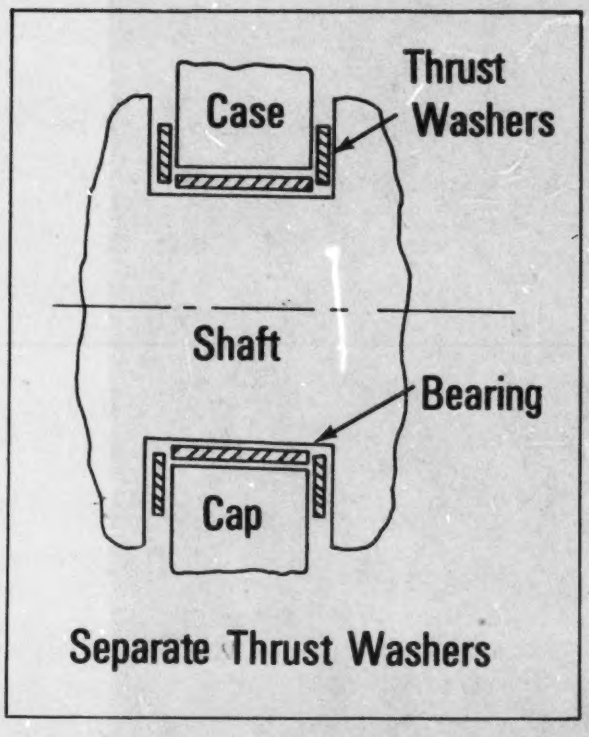
Bearing Crush



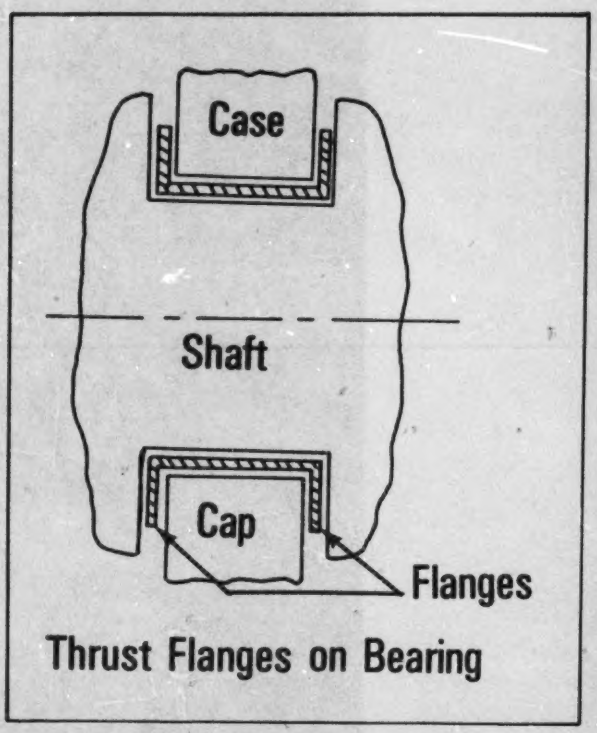
Bearing Oil Grooves



Types of Thrust Bearings



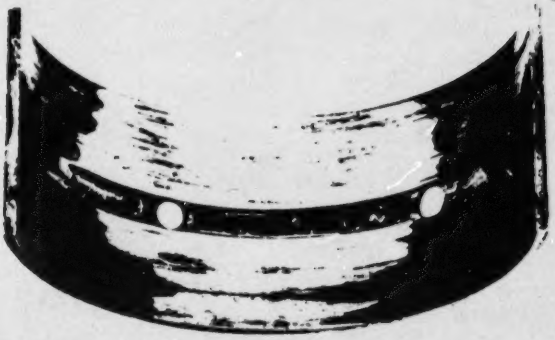
Separate Thrust Washers



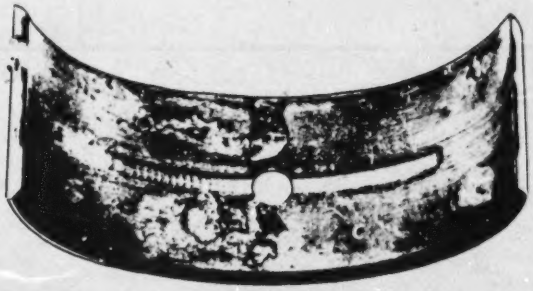
Thrust Flanges on Bearing

Causes of Bearing Failure

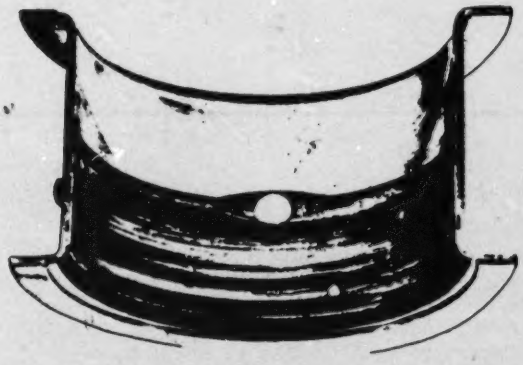
Damage From Dirt
Embedded In Bearing



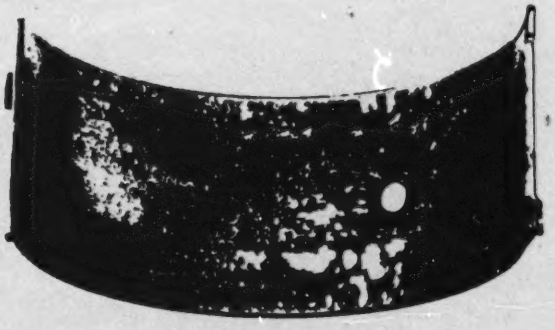
Oil Starvation Caused This Damage



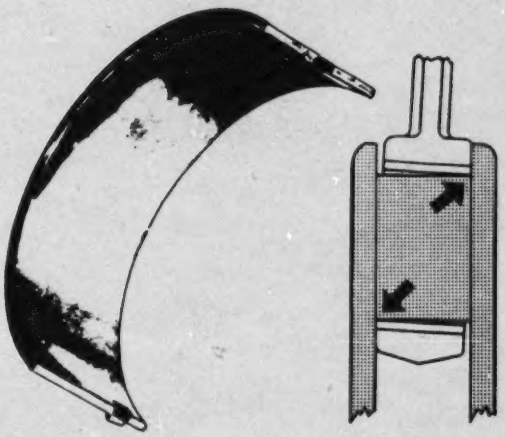
Bearing Fatigue Caused By
Overloading and Heat



Wear On One Edge of Bearing
Caused by Tapered Journals



Corrosion From Acid
Formation In Oil



Excessive Wear Caused
by a Bent Connecting Rod

CRANKSHAFTS AND BEARINGS
UNIT V

JOB SHEET #1--DISASSEMBLE, INSPECT, AND
REPLACE CRANKSHAFT ASSEMBLY AND ENGINE BEARINGS

I. Tools and Materials

A. Basic hand tool set

B. V-Blocks

C. Engine short block

D. Outside micrometers

E. Inside micrometers

F. Out-of-roundness indicators

G. Shoulder arbor

H. Cam bearing assembly tool

I. Steam supply

J. Compressed air supply

K. Solvent

L. Eye protection

M. Shop towels

N. Appropriate service manual

II. Procedure

A. Disassemble crankshaft assembly

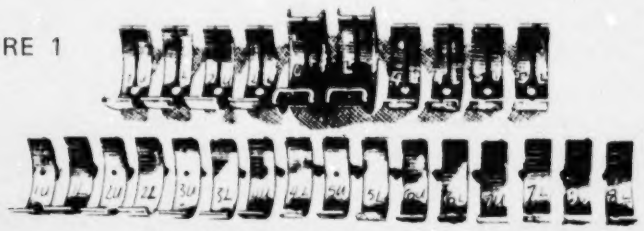
(NOTE: Be sure connecting rod blades and caps are marked as to position in engine (#1, #2, and so on) and on which side all of the markings are. If there are no markings, mark accordingly with a numeral stamp.

1. Remove rod caps

JOB SHEET #1

2. Remove the bearings from the cap and blade and mark their position in the lining, 1U, 1L in the case of number 1 connecting rod upper and lower bearing (Figure 1)

FIGURE 1



3. Repeat step number two for main bearings caps and bearings

4. Wash all bearings and set out on bench in proper order for subsequent analysis

5. Remove camshaft

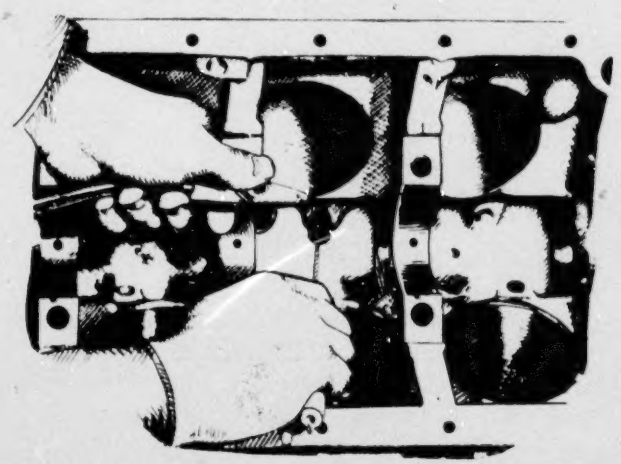
6. Remove crankshaft and place on V-blocks

7. Thoroughly clean cylinder block, crankshaft, and camshaft

8. Rinse in clean solvent

9. Clean oil passageways and holes with brush and water pressure or brush and compressed air (Figure 2)

FIGURE 2



JOB SHEET #1

B. Inspect crankshaft

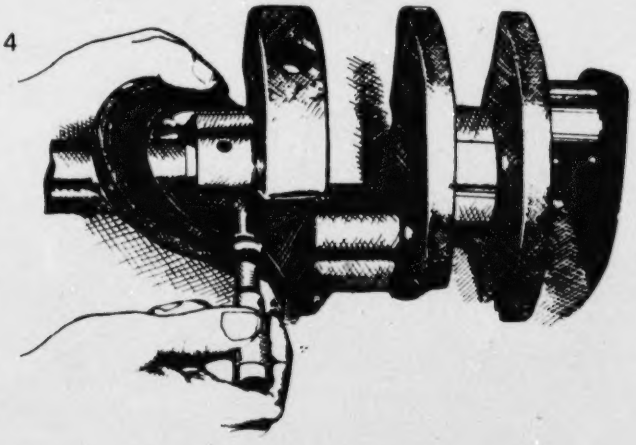
(NOTE: Use the chart given to record the following readings. See Figure 3.)

FIGURE 3

	MAIN BEARING #1	MAIN BEARING #2	MAIN BEARING #3	MAIN BEARING #4	MAIN BEARING #5	MAIN BEARING #6	MAIN BEARING #7
HORIZONTAL							
VERTICAL							
	CONNECTING ROD BEARING #1	CONNECTING ROD BEARING #2	CONNECTING ROD BEARING # 3	CONNECTING ROD BEARING #4	CONNECTING ROD BEARING #5	CONNECTING ROD BEARING #6	
HORIZONTAL							
VERTICAL							

1. Take readings all around one journal to find the smallest diameter as a starting point. (Figure 4)

FIGURE 4



2. Take three readings in line on the journal.

   (NOTE: Take one reading at the smallest end, one in the center, and one at the other end of the journal.)

3. Record readings on chart to show amount of taper

4. Rotate journal 90° or one quarter of a turn.

JOB SHEET #1

5. Take three readings in line

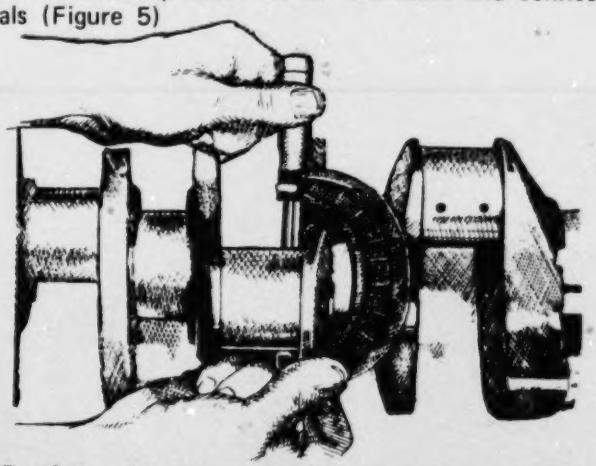
(NOTE: Take the first at one end, the second in the middle, and the third at the other end, and record them. If the first three readings were horizontal, the second three would be vertical or vice versa. The second three readings show the amount of taper in that line of the journal.)

6. Compare the first horizontal reading with the first vertical reading, the second horizontal reading with the second vertical reading, and the third horizontal reading with the third vertical reading

(NOTE: This will show the amount of out-of-round of the journal.)

7. Repeat the above process for all the main and connecting-rod journals (Figure 5)

FIGURE 5



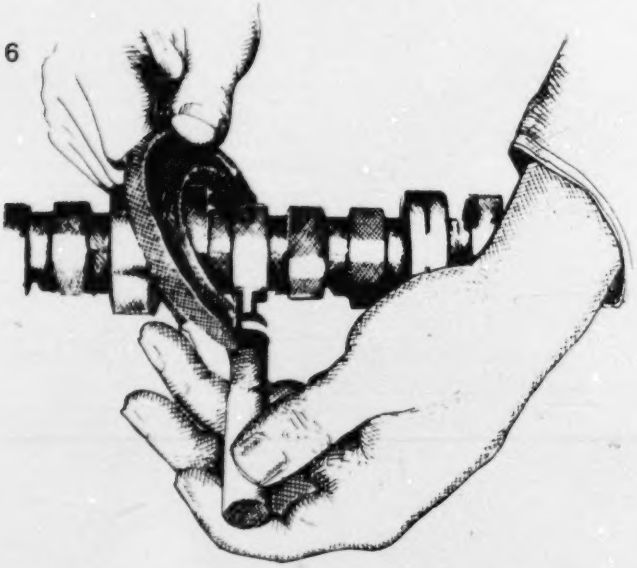
(NOTE: If any journal or crankpin is below specifications for taper or out-of-round, crankshaft should be reground to a smooth, accurate undersize.)

JOB SHEET #1

C. Inspect camshaft

1. Measure the height of cam lobes (Figure 6)

FIGURE 6

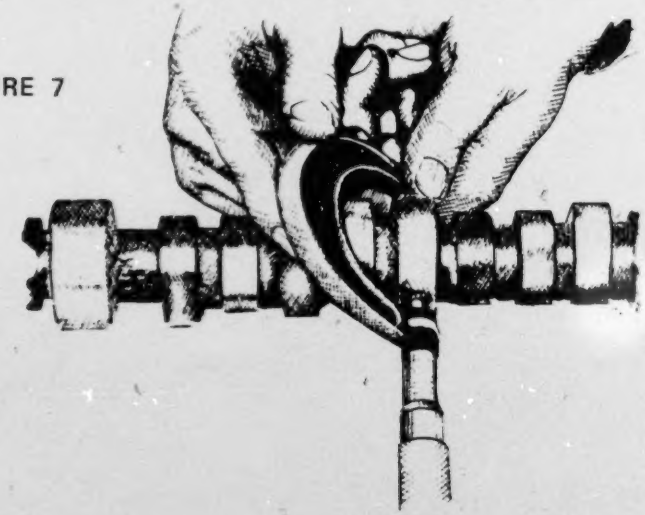


2. Compare the height of lobes

(NOTE: Compare one intake against the other intake, and exhaust against the other exhaust until completed. If wear exceeds limitations camshaft should be reground or replaced.)

3. Measure the camshaft journals in several places around the periphery starting from the timing gear end. (Figure 7)

FIGURE 7



JOB SHEET #1

4. Record the maximum and the minimum measurements obtained for each journal (Figure 8)

(NOTE: If any journal is .001" below the established low limit specifications, it should be reground to a standard undersize.)

FIGURE 8

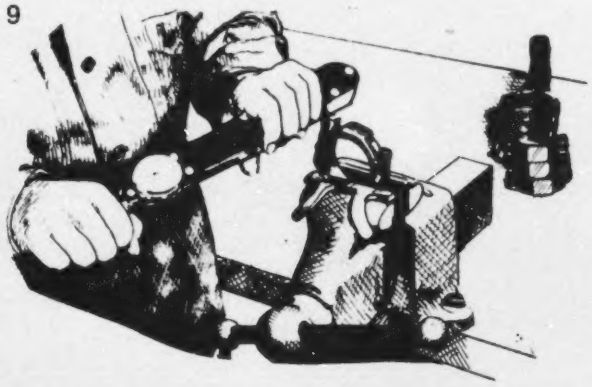
D. Inspect connecting rods

1. Assemble the number one cap onto the number one connecting rod

2. Tighten the rod nuts lightly, tapping the cap with a plastic mallet to seat it properly

3. Tighten the nuts to the correct torque specifications and repeat this operation with the rest of the rods (Figure 9)

FIGURE 9

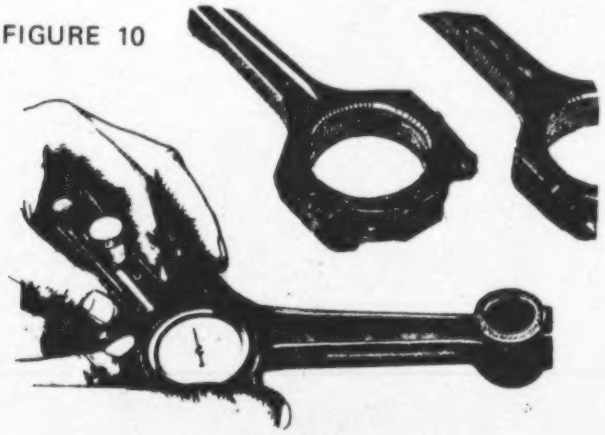


JOB SHEET #1

4. Check each connecting rod bore with an out-of-roundness indicator

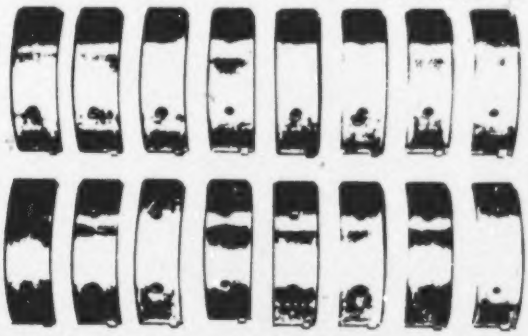
(NOTE: If the out-of-roundness of any rod is found to be greater than .001" that rod must be replaced. See Figure 10.)

FIGURE 10



5. Examine the backs of the old rod bearings for signs that indicate that some of the rod bores are oversized (Figure 11)

FIGURE 11



(NOTE: A rod bearing that had failed for no apparent reason or the backs of the bearings that show excessive movement would make that connecting rod open to suspicion.)

6. Replace any rod that has been determined unfit for further use

E. Assemble engine

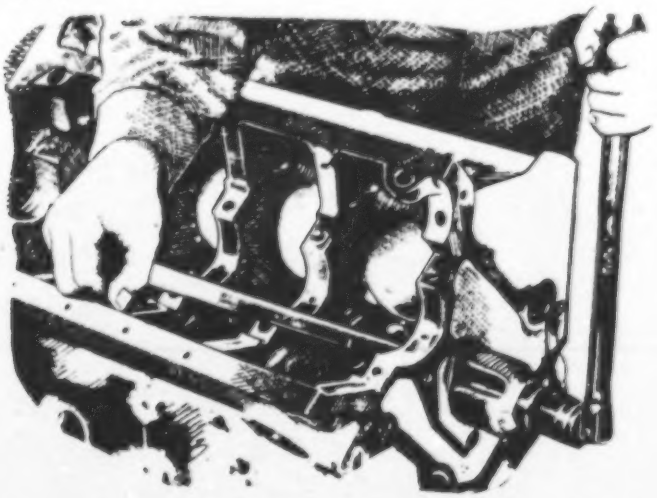
1. Check all new bearings against the rod for correct alignment of locking lips, oil grooves, oil holes

(NOTE: Make sure all parts are cleaned and crankshaft and camshaft journals tagged for amount of undersize if reground.)

JOB SHEET #1

2. Using a shoulder arbor of the proper size and a suitable cam bearing assembly tool, line up the oil holes and press each cam bearing into place (Figure 12)

FIGURE 12



(NOTE: After the bearings have been installed, check to make sure the oil hole or holes in the bearings are aligned exactly with those in the crankcase.)

3. Wipe off each cam bearing bore with a clean cloth

4. Spread clean oil on the inner surface

5. Carefully insert the camshaft

(NOTE: If the crankshaft has been reground, clean it again very thoroughly with a brush and plenty of solvent.)

6. Clean out all of the oil-ways with a wire-handled rifle brush

JOB SHEET #1

7. Blow them out with clean, demoisturized air or flush them with clean solvent (Figure 13)

FIGURE 13

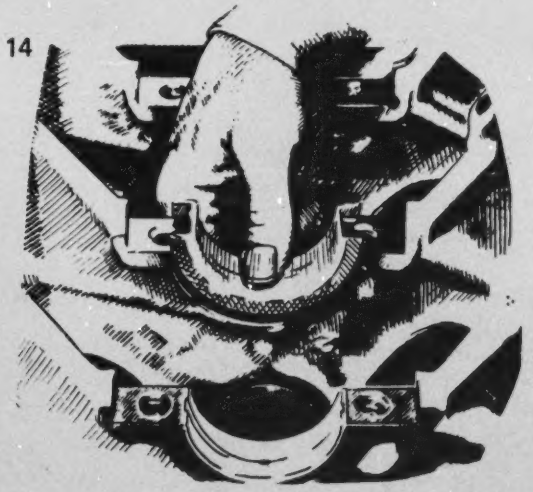
(NOTE: This is very important because metal chips or particles in the oil-ways can damage the bearings.)

8. Place the upper main bearing halves in the crankcase saddles and "snap" them into their seats

(NOTE: Make sure that each locking lip nests into the recess provided.)

9. Apply a few drops of clean oil to the bearings and spread it over the surfaces with a clean finger (Figure 14)

FIGURE 14



JOB SHEET #1

10. Wipe off the crankshaft journals with a clean cloth

11. Carefully position the shaft on the bearings

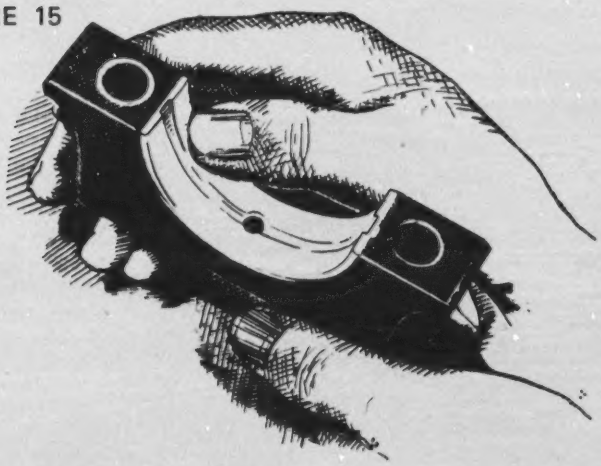
(NOTE: Be sure to hold the shaft parallel to the case bores and gently lower it into position. This must be done with extreme care because the thrust bearing thrust surfaces can be easily damaged.)

12. Wipe off each main bearing cap bore

13. Position the bearings in the bores, and snap them into their seats

(NOTE: Check to see that each locking lip nests properly in its recess. Apply a few drops of oil on each bearing and spread it over the surface. See Figure 15.)

FIGURE 15



14. Install the main bearing caps

(NOTE: Check the cap markings for position in the engine and for position in relation to the front of the engine.)

15. Install and tighten the cap screws or stud nuts finger tight

(NOTE: Tap each cap with a plastic or leather mallet to help it find its natural position.)

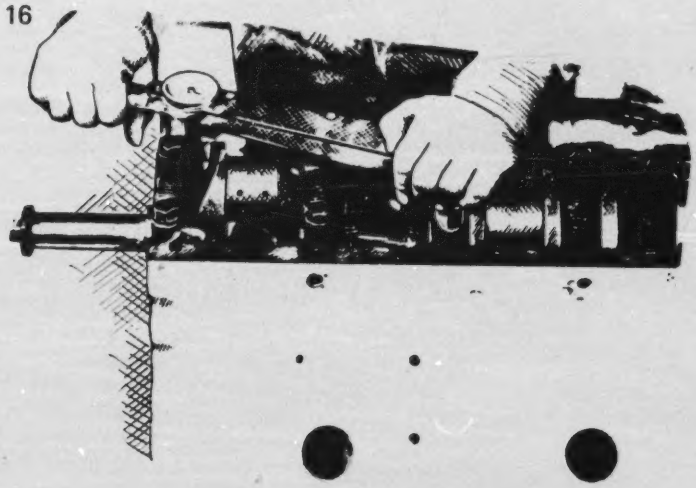
16. Using a pry bar, force the crankshaft forward until the rear faces of the thrust flanges are properly aligned

JOB SHEET #1

17. When the thrust flanges are aligned, tighten all of the nuts alternately to be fairly snug

18. Final tighten each nut to the proper torque limit specification (Figure 16)

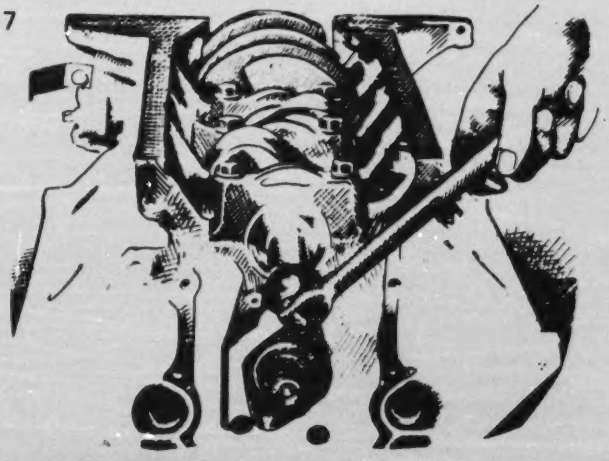
FIGURE 16



19. After the nuts have all been torqued using a suitable tool, rotate the crankshaft by hand

(NOTE: If the job has been done properly up to now, the shaft should turn reasonably free. See Figure 17.)

FIGURE 17



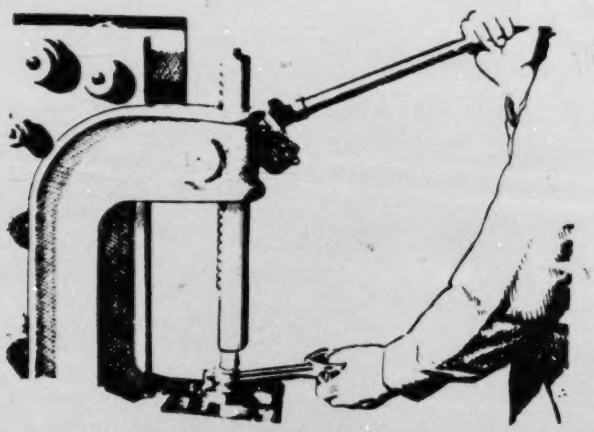
20. Check crankcase oil clearance according to manufacturer's specifications

JOB SHEET #1

21. Install cotter pins or lock nuts

(NOTE: If the connecting rods are to be reused, press out the piston pin bushings and install new ones of the proper size to permit piston pin fitting. See Figure 18.)

FIGURE 18



22. Size each bushing, as necessary, to fit the piston pins

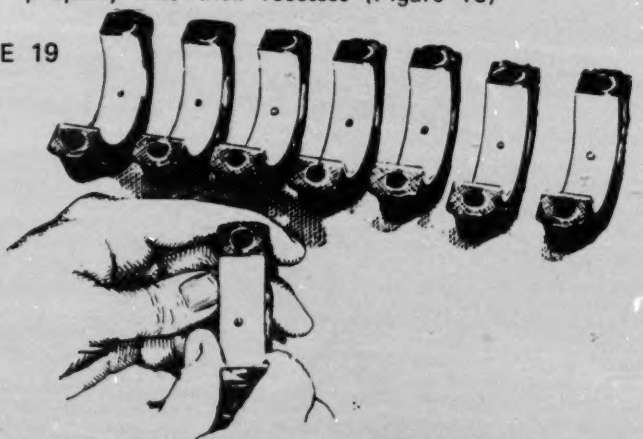
23. Clean each rod again, particularly the oil-way

24. Assemble the pistons, piston pins, lock rings, and piston rings

25. Wipe off the connecting rod cap bores and the backs of the lower bearing inserts with a clean shop towel

26. Install a bearing into each cap, making sure the locking lips nest properly into their recesses (Figure 19)

FIGURE 19



(CAUTION: Keep dry hands off bearings.)

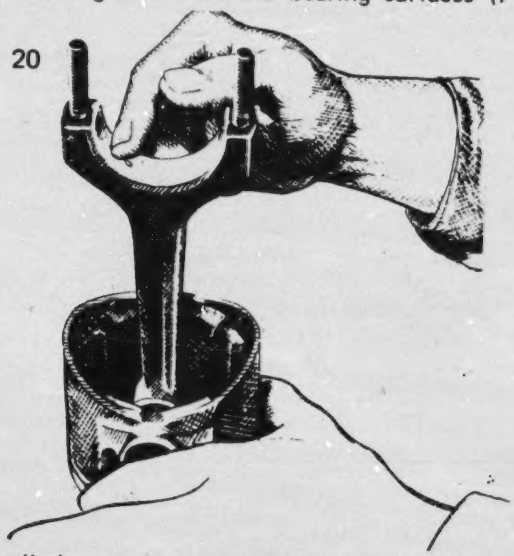
JOB SHEET #1

27. Wipe out the connecting rod blade bores and the back of the upper half bearing inserts

28. Install the bearings in the blade bores on the rod and piston assemblies

29. Spread engine oil on the bearing surfaces (Figure 20)

FIGURE 20

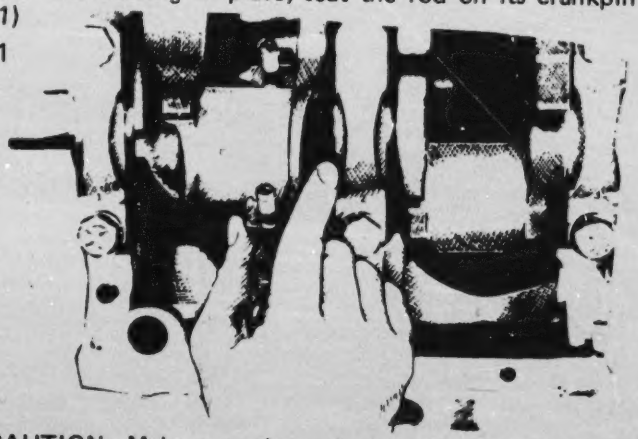


30. Install the number one piston rod assembly into the number one cylinder

(Note: Make sure the rod reference is in correct relation to the front of the engine.)

31. With the bearing in place, seat the rod on its crankpin (Figure 21)

FIGURE 21



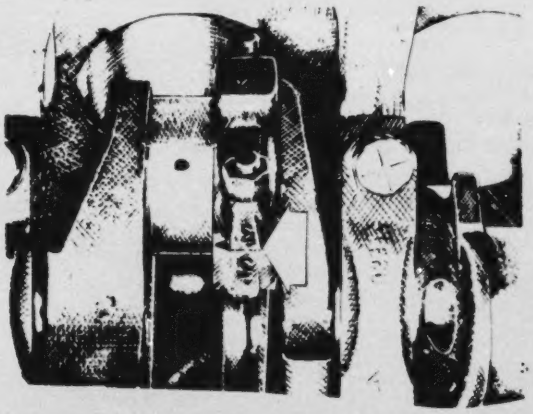
(CAUTION: Make sure the rod studs do not touch and damage the crankpin when the rod is being installed.)

JOB SHEET #1

32. Spread oil on the connecting rod cap bearing surface

33. Install the number one rod cap and turn the nuts down finger tight (Figure 22)

FIGURE 22



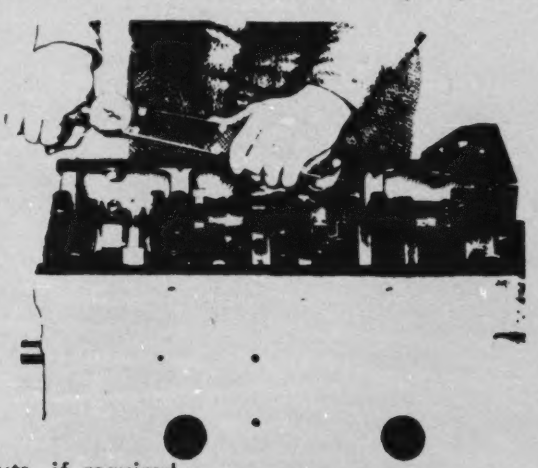
(NOTE: Make sure that the rod cap and blade markings are on the same side.)

34. Install the other rod caps in the same manner

35. Tap each cap with a plastic mallet to help seat it in its proper position

36. Tighten all rod nuts to the recommended torque specifications (Figure 23)

FIGURE 23



37. Install locknuts, if required

38. Install oil pump and other parts

39. Attach the engine pre-lubricator to check the bearing job and to prevent "dry starts"

CRANKSHAFTS AND BEARINGS
UNIT V

NAME_____

TEST

1. Match the terms on the right to the correct definitions.

_____a.	Made from a single billet of steel	1. Dynamically balanced
_____b.	That part of a shaft or axle in contact with the bearing	2. Short block
_____c.	Two crankshaft webs and one crankpin	3. Crankpin
_____d.	Forms the crank or throw between the crankpin and main journal	4. Bushing
_____e.	Outer end of crank throw	5. Vibration damper
_____f.	Reduces torsional stress on the crankshaft caused by power strokes and the loads on the engine	6. Statically balanced
_____g.	Balanced while at rest	7. Bearing
_____h.	Balanced against the rotary outward force at high speed	8. Crankshaft throw
_____i.	Full round sleeve normally used to support light loads	9. Crankshaft web
_____j.	Half round sleeve normally used to support heavy loads	10. Journal
_____k.	Measured difference between the inside diameter of the bearing and the outside diameter of the journal	11. Integral crankshaft
_____l.	Engine block without cylinder head and external accessories	12. Bearing clearance

2. Name four types of crankshaft construction.

a.

b.

c.

d.

3. Name six parts of a crankshaft.

   a.

   b.

   c.

   d.

   e.

   f.

4. List three effects of the arrangement of crankshaft throws.

   a.

   b.

   c.

5. Match the arrangement of crankshaft throws on the right to the number of cylinders in the engine.

_____a.	Two and four cylinder	1.	Throws 90° apart
_____b.	Three and six cylinder	2.	Throws 180° apart
_____c.	Eight cylinder	3.	Throws 120° apart

6. Name three ways crankshaft balance is maintained.

   a.

   b.

   c.

7. Explain the lubrication of the crankshaft and surrounding parts.

8. Distinguish between a bushing and a bearing by placing an "X" next to the description of a bushing.

   _____a. A half round sleeve used to support heavy loads and high speeds

   _____b. A fully round sleeve used to support light loads and slow speeds

9. Name three materials used in making bearing linings.

   a.

   b.

   c.

10. Name two types of bearing locks.

    a.

    b.

11. Explain what is meant by bearing crush.

12. State the purpose of oil grooves in the bearing.

13. Name two types of thrust bearings.

    a.

    b.

14. List three engine indications of bearing failure.

    a.

    b.

    c.

15. Match the percentages of bearing failures on the right to the causes of bearing failure.

_____a. Dirt	1. 9 percent
_____b. Lack of lubrication	2. 14 percent
_____c. Improper assembly	3. 16 percent
_____d. Misalignment	4. 10 percent
_____e. Overloading	5. 43 percent

16. List four functions of the flywheel.

    a.

    b.

    c.

    d.

17. Demonstrate the ability to disassemble, inspect, and replace crankshaft assembly and engine bearings.

    (NOTE: If this has not been accomplished prior to the test, ask your instructor when it should be completed.)

CRANKSHAFTS AND BEARINGS
UNIT V

ANSWERS TO TEST

1. a. 11
   b. 10
   c. 8
   d. 9
   e. 3
   f. 5
   g. 6
   h. 1
   i. 4
   j. 7
   k. 12
   l. 2
2. a. Integral
   b. Sectional
   c. Semi-built-up
   d. Built-up
3. a. Main bearing journals
   b. Connecting rod bearing journals
   c. Connecting rod counterweights
   d. Flywheel hub or flange
   e. Crankshaft gear
   f. Crankshaft throw
4. Any three of the following:
   a. Balance the engine
   b. Smooth vibrations of turning shaft
   c. Equalize loads on the main bearings
   d. Determine the firing order of engine
5. a. 2
   b. 3
   c. 1

6. a. Counterweights

   b. Vibration damper

   c. Flywheel

7. Explanation should include:

   a. Oil pressure through holes in journals

   b. Oil spray from excess

8. b

9. a. Tin or lead base babbit

   b. Copper or aluminum alloys

   c. Multilayers of copper or aluminum alloys and silver combinations

10. a. Lip slot

    b. Dowel

11. Explanation should include--Height of bearing insert above bearing cap to allow for a fully seated bearing when tightened

12. Bearing oil grooves carry the oil through to the connecting rod

13. a. Separate thrust washers

    b. Thrust flanges on bearings

14. a. Drop in lubricating oil pressure

    b. Excessive oil consumption

    c. Engine noise--Rythmic knock

15. a. 5

    b. 3

    c. 2

    d. 4

    e. 1

16. Any four of the following:

    a. Stores energy for momentum between power strokes

    b. Smooths out speed of crankshaft

    c. Transmits power to driven machine

    d. Provides a drive for starter via ring gear

    e. Serves as a facing for engine clutch

17. Performance skills evaluated to the satisfaction of the instructor

LUBRICATION SYSTEMS
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify the components of the lubrication system and match the components to their purposes. The student should be able to list the types of lubrication systems and discuss the water and oil circulation in an oil cooler. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with the lubrication system to the correct definitions.
2. List five functions of the lubrication system.
3. List three types of lubrication systems.
4. Identify the components of the lubrication system.
5. Match the components of the lubrication system to their purposes.
6. Identify two types of oil filters.
7. Name types of oil pumps.
8. List sources of oil contamination.
9. List the purposes of lubricating valves.
10. Discuss the water and oil circulation in an oil cooler.
11. Discuss two types of oil pressure indicating systems.
12. Demonstrate the ability to check and adjust oil pressure on a live engine.

LUBRICATION SYSTEMS
UNIT I

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information and job sheet.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined in the job sheet.

G. Invite company representative to discuss lubricating oils.

H. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete job sheet.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1–Functions of the Lubrication System
2. TM 2–Types of Lubrication Systems
3. TM 3–Components of the Lubrication System

4. TM 4--Types of Oil Filters
5. TM 5--Types of Oil Pumps
6. TM 6--Types of Oil Pumps (Continued)
7. TM 7--Types of Oil Pumps (Continued)
8. TM 8--Lubricating Valves
9. TM 9--Oil Coolers
10. TM 10--Mechanical Oil Pressure Indicating System
11. TM 11--Electrical Oil Pressure Indicating System

D. Job Sheet #1--Check and Adjust Oil Pressure on a Live Engine

E. Test

F. Answers to test

II. References:

A. Kates, Edgar J. and Luck, William E. *Diesel and High Compression Gas Engines*. Chicago: American Technical Society, 1974.

B. *Fundamentals of Service: Engines.* Moline, Illinois: Deere and Company, 1972.

LUBRICATION SYSTEMS
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Friction--Resistance to movement between any two objects placed in contact with each other

B. Viscosity--Measure of an oil's ability to flow

C. API--American Petroleum Institute

D. SAE--Society of Automotive Engineers

E. Gallery--Pipe or passageway in the engine used to carry engine oil from one area to another

II. Functions of the lubrication system (Transparency 1)

A. Reduces friction between moving parts

B. Absorbs and dissipates heat

C. Seals the piston rings and cylinder walls

D. Cleans and flushes moving parts

E. Helps deaden the noise of the engine

III. Types of lubrication systems (Transparency 2)

A. Circulating splash

B. Internal force feed and splash

C. Full internal force feed

(NOTE: The full internal force feed system, in addition to other parts, supplies oil under pressure to the piston pins.)

IV. Components of the lubrication system (Transparency 3)

A. Oil galleries

B. Oil filter

C. Pressure regulating valve

INFORMATION SHEET

D. Oil pump

E. Oil pan

F. Pressure gauge

G. Engine bearings

V. Purposes of components of the lubrication system

A. Oil galleries--Carry engine oil from one area to another

B. Oil filter--Strains the engine oil removing abrasive particles

C. Pressure regulating valve--Limits the maximum oil pressure

D. Oil pump--Forces oil under pressure to various parts of the engine for lubrication

E. Oil pan--Provides a reservoir for the engine oil

F. Pressure gauge--Indicates oil pressure during engine operation

G. Oil cooler-Engine coolant flows through this and helps dissipate the heat in the engine oil

VI. Types of oil filters (Transparency 4)

A. Surface filter - wire mesh type

(NOTE: Oil passes straight through tiny surface holes.)

B. Depth filter - cotton waste type

(NOTE: Oil moves in many directions before passing through filter to lubrication system.)

VII. Types of oil pumps (Transparencies 5, 6, and 7)

A. Gear

B. Rotor

C. Vane

(NOTE: All types are positive displacement pumps.)

INFORMATION SHEET

VIII. Sources of oil contamination

A. Storing and handling

B. Dust from air that is breathed into engine

C. Improper engine warm-up

D. Antifreeze leaking into oil supply

E. Oxidation

F. Carbon particles

G. Engine wear

H. Fuel dilution

IX. Purposes of lubricating valves (Transparency 8)

A. Regulate oil pressure

B. Bypass oil at filters and oil coolers

(NOTE: The oil pressure regulating valve maintains the correct pressure in the lubricating system regardless of engine speed or the temperature of the oil.)

X. Oil cooler circulation (Transparency 9)

A. Internally mounted--Engine coolant is pumped by water pump through oil cooler mounted in the crankcase and back to the radiator where the heat is dissipated

B. Externally mounted--Both water and oil are pumped through the oil cooler

(NOTE: Oil coolers are also known as heat exchangers.)

XI. Oil pressure indicating systems

A. Mechanical--Bourdon tube gauge which tends to straighten out when pressure is applied (Transparency 10)

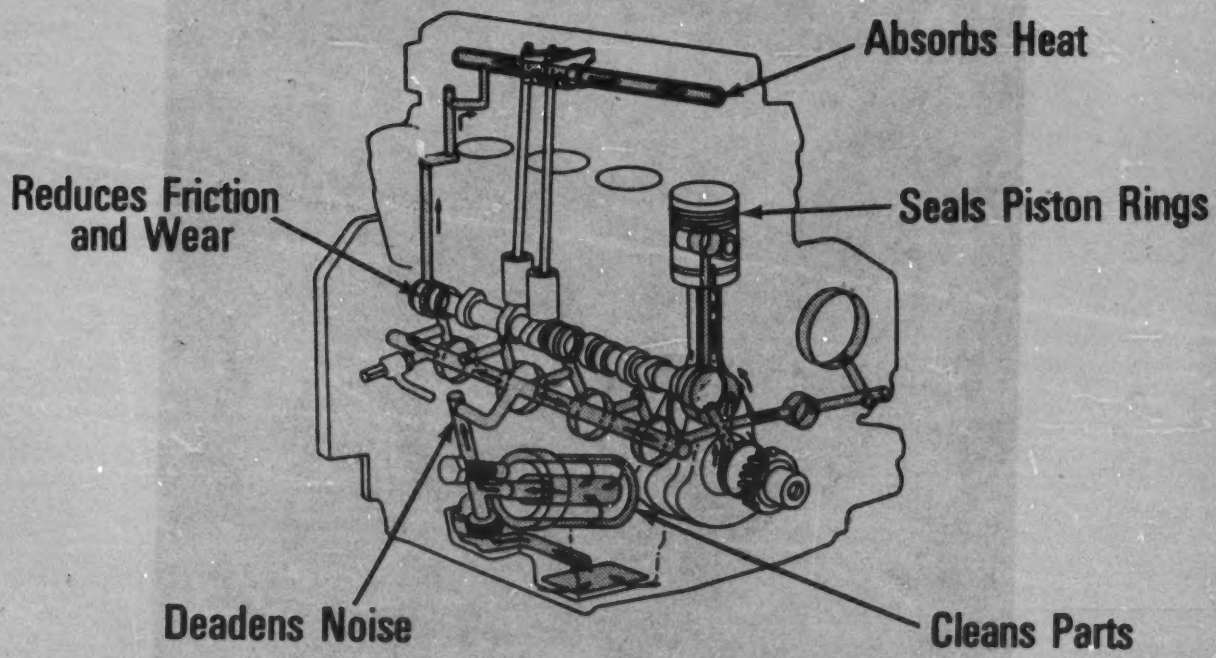
B. Electrical (Transparency 11)

1. Sending unit is at pressure source

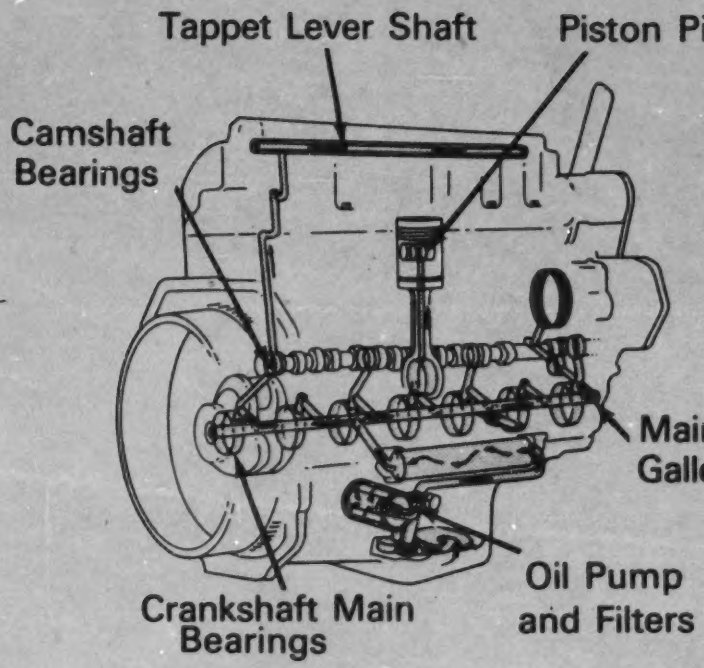
2. Indicating gauge is on control panel

(NOTE: Electrical indicating systems may be three types: electromagnetic coil, heating coil, or pressure switch system.)

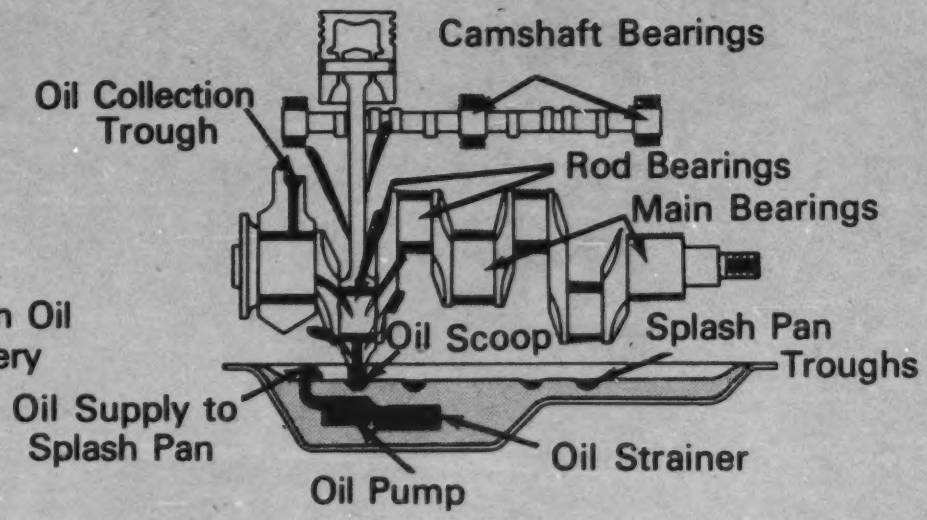
Functions of the Lubrication System



Types of Lubrication Systems

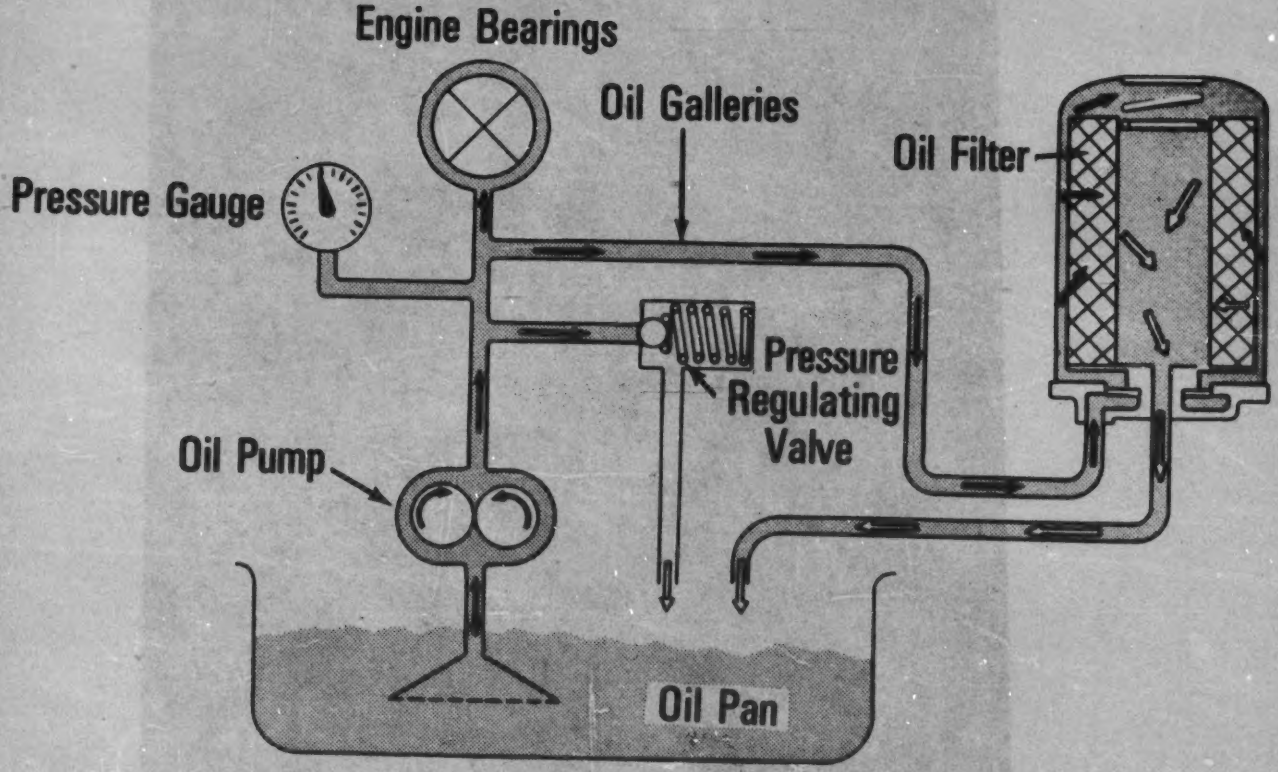


Full Internal Force Feed

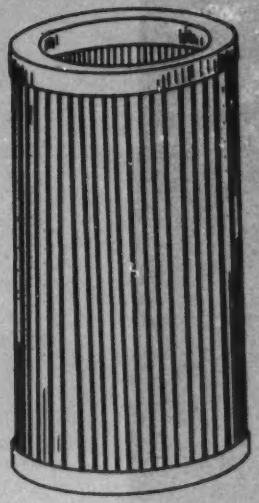


Circulating Splash System

Components of the Lubrication System



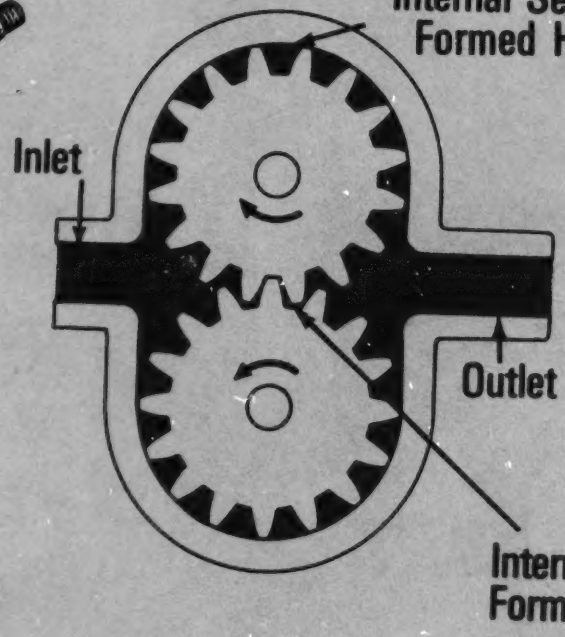
Types of Oil Filters



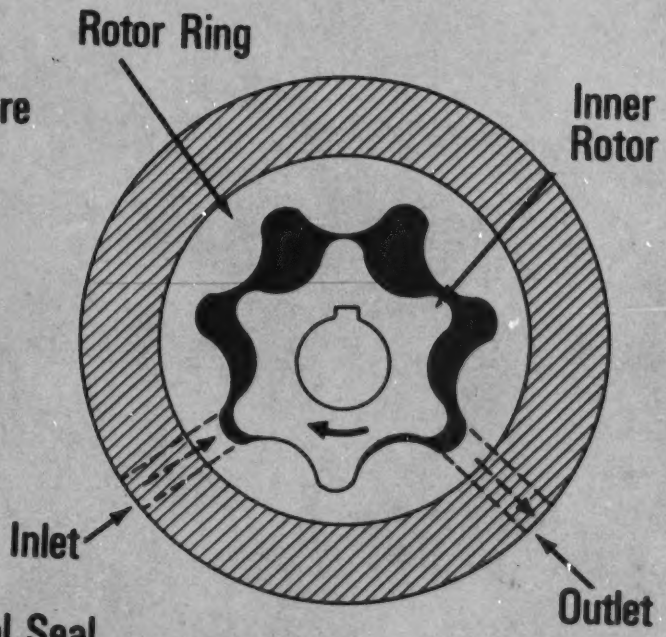
Surface Filter--Wire Mesh Type

Depth Filter--Cotton Waste Type

Types of Oil Pumps

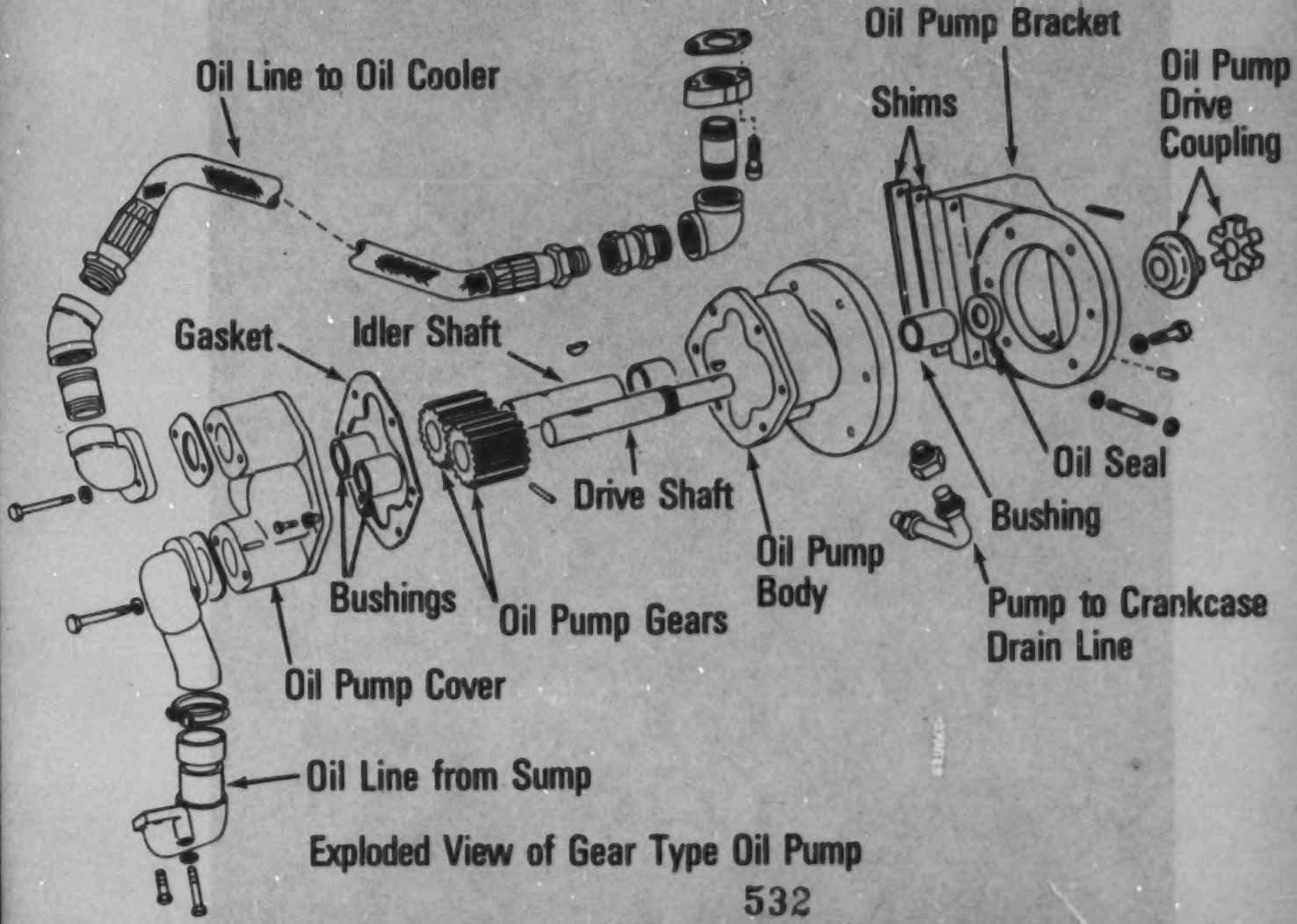


External Gear Pump



Rotor Pump

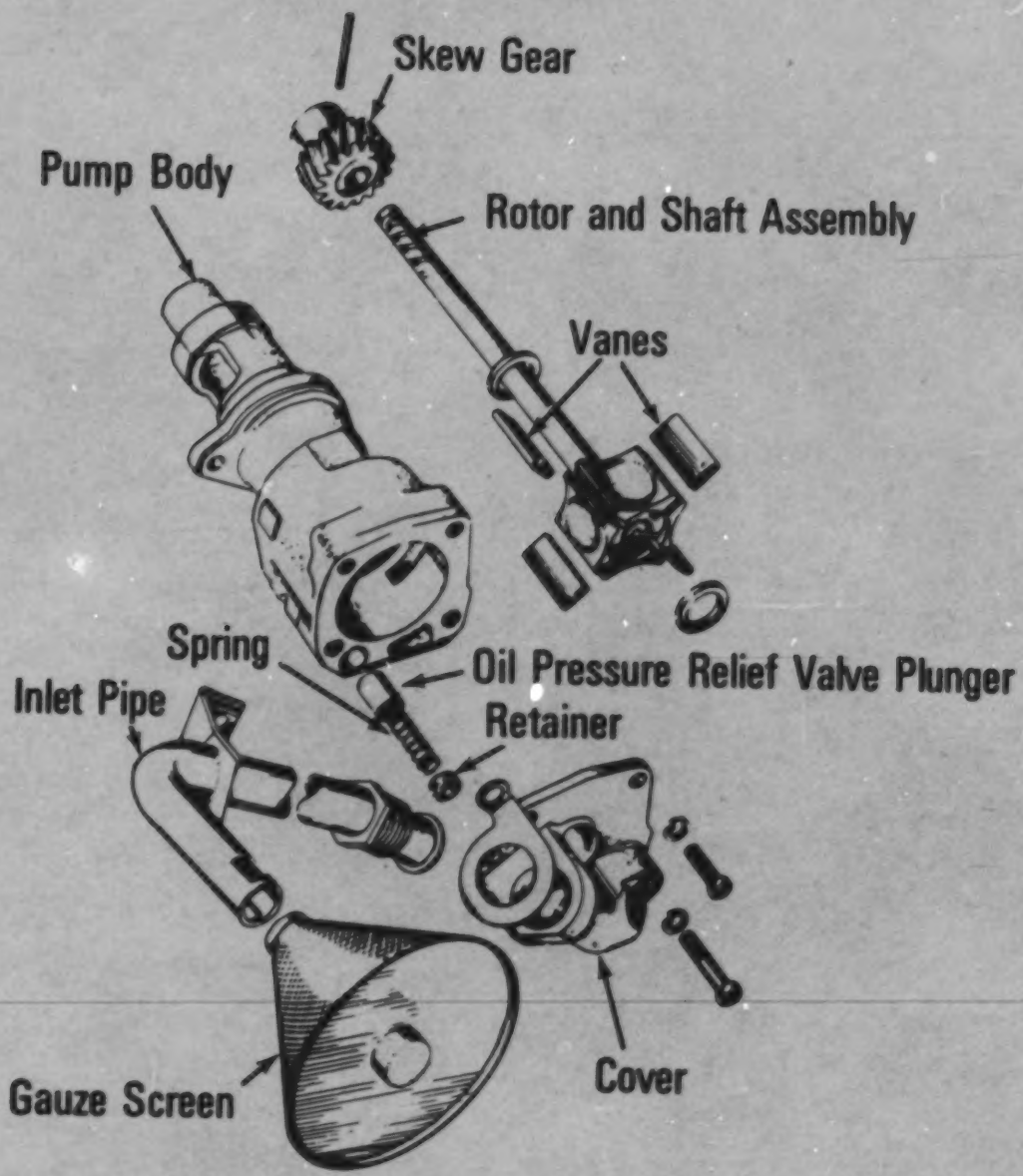
Types of Oil Pumps (Continued)



Exploded View of Gear Type Oil Pump

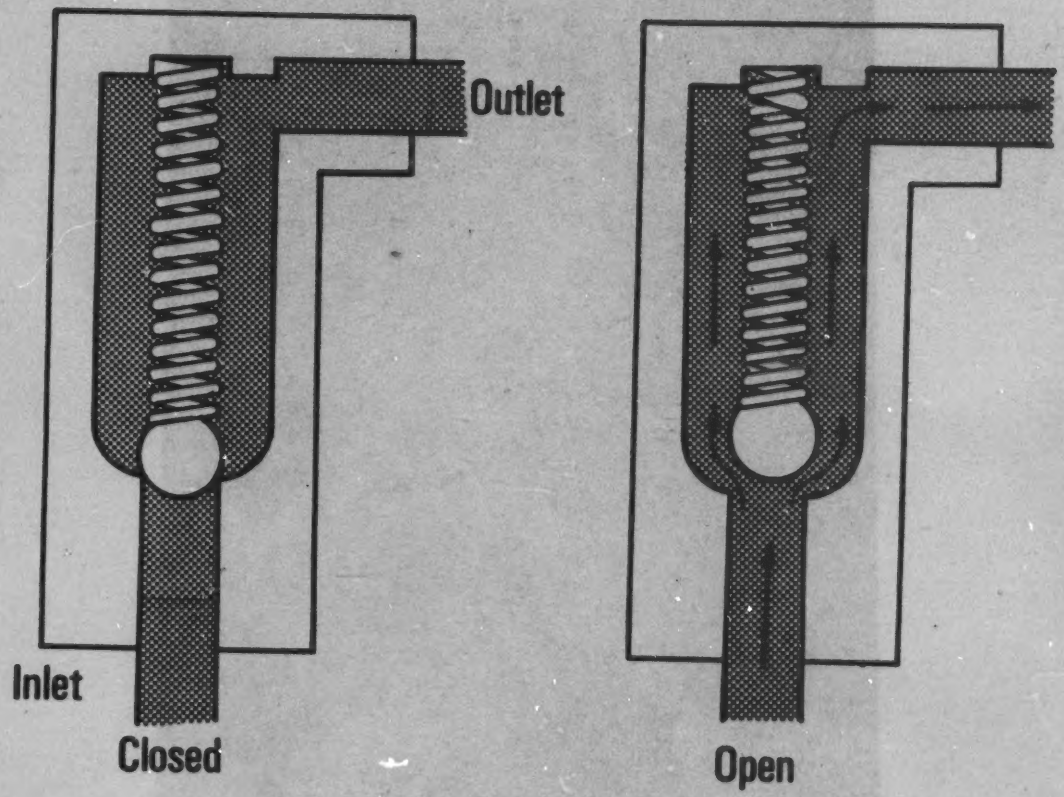
Types of Oil Pumps

(Continued)

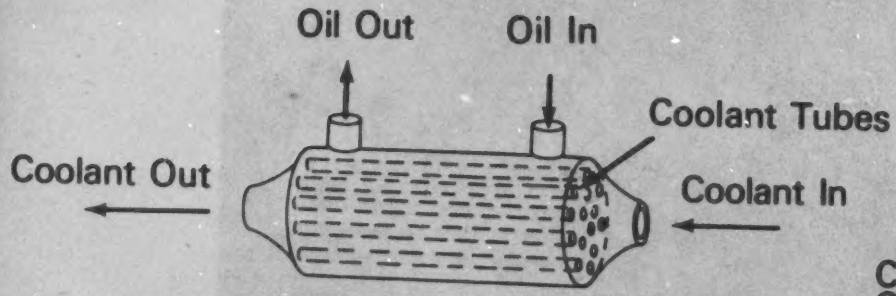


Vane Type Oil Pump

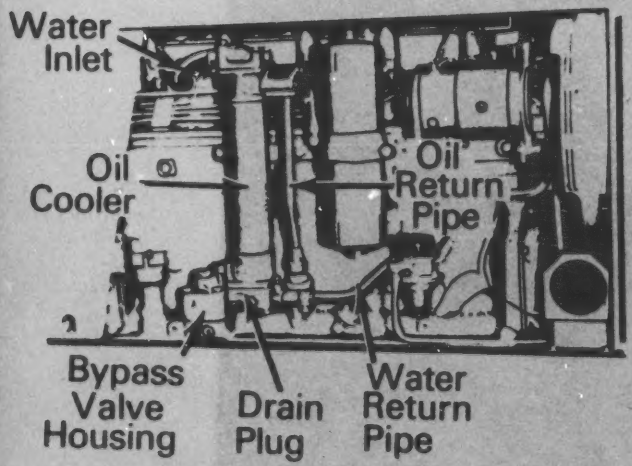
Lubricating Valves



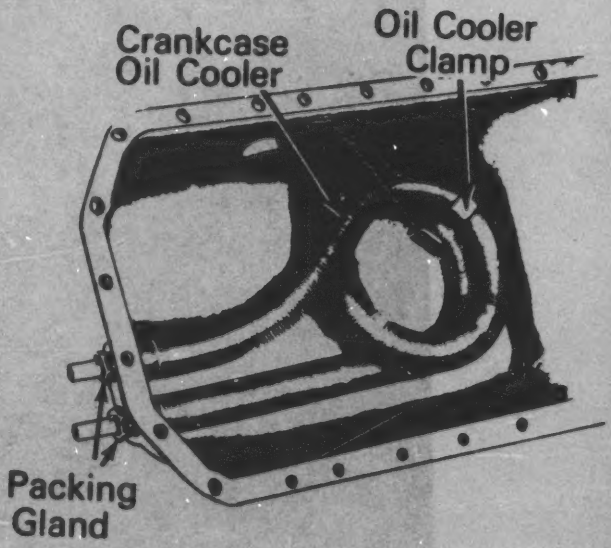
Oil Coolers



Operation of Engine Oil Cooler

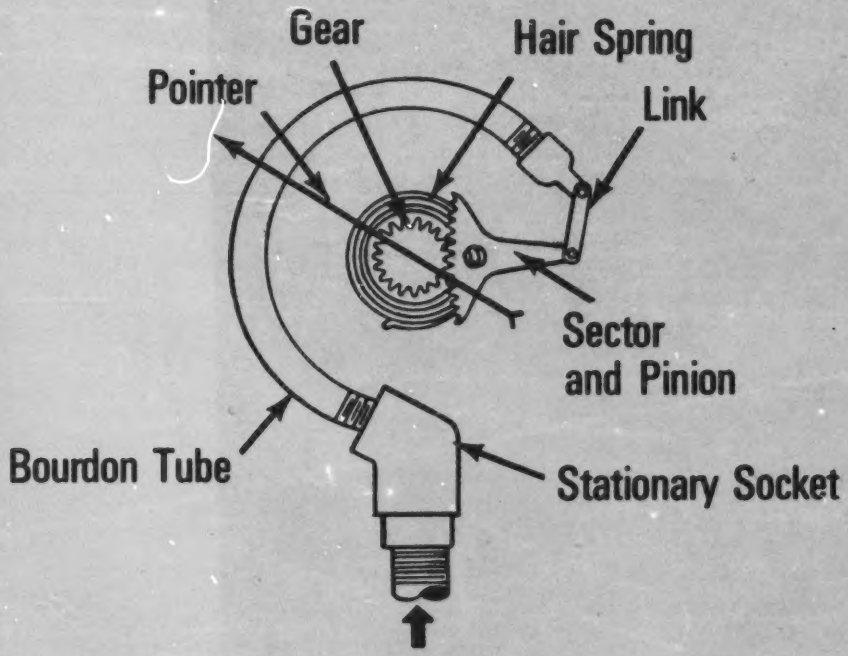


Internally Mounted

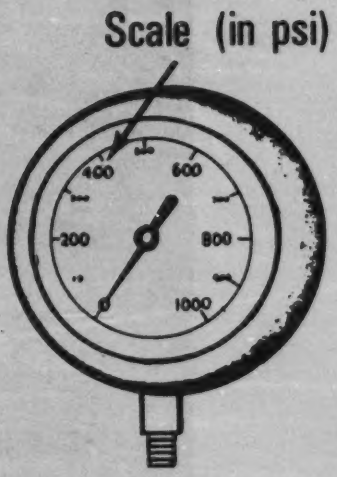


Externally Mounted

Mechanical Oil Pressure Indicating System



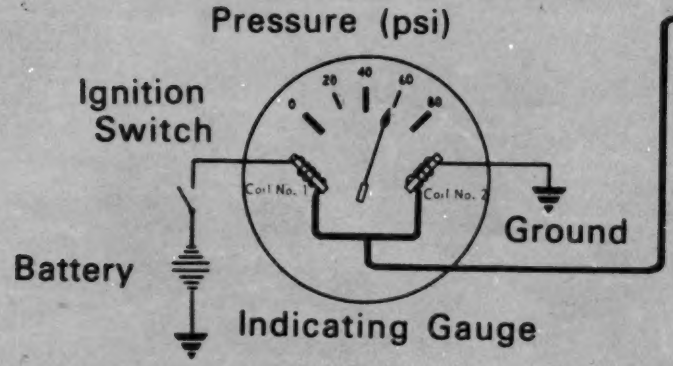
Bourdon Tube Oil Gauge

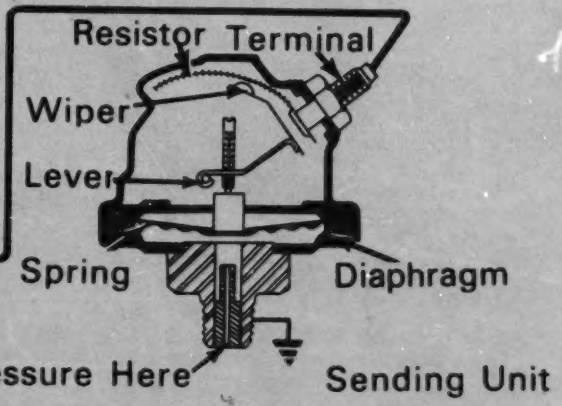


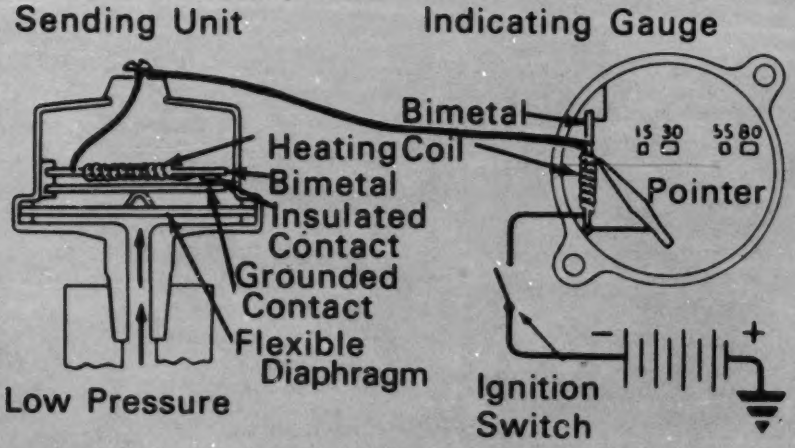
Complete Gauge

Electrical Oil Pressure Indicating Systems

Electromagnetic Coil System for Indicating Oil Pressure

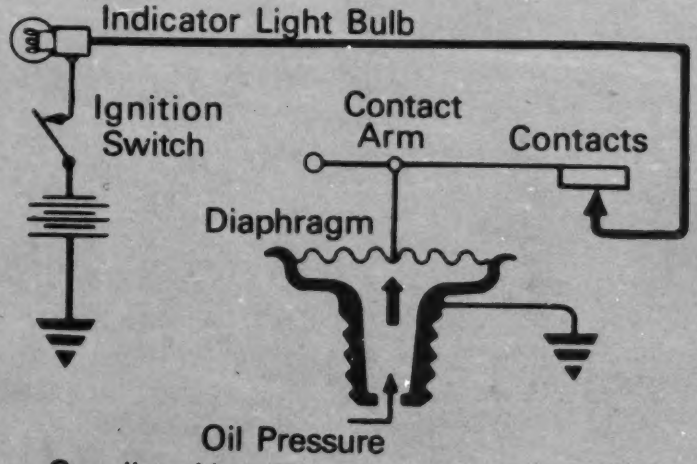






Operation with Low Oil Pressure

Heating Coil System for Indicating Oil Pressure



Sending Unit (Pressure Switch)

Pressure Switch System for Indicating Oil Pressure

LUBRICATION SYSTEMS
UNIT I

JOB SHEET #1--CHECK AND ADJUST OIL PRESSURE
ON A LIVE ENGINE

I. Tools and equipment

A. Screwdriver

B. Master pressure gauge

C. End wrench

D. Shop towel

E. Shim stock for regulating valve

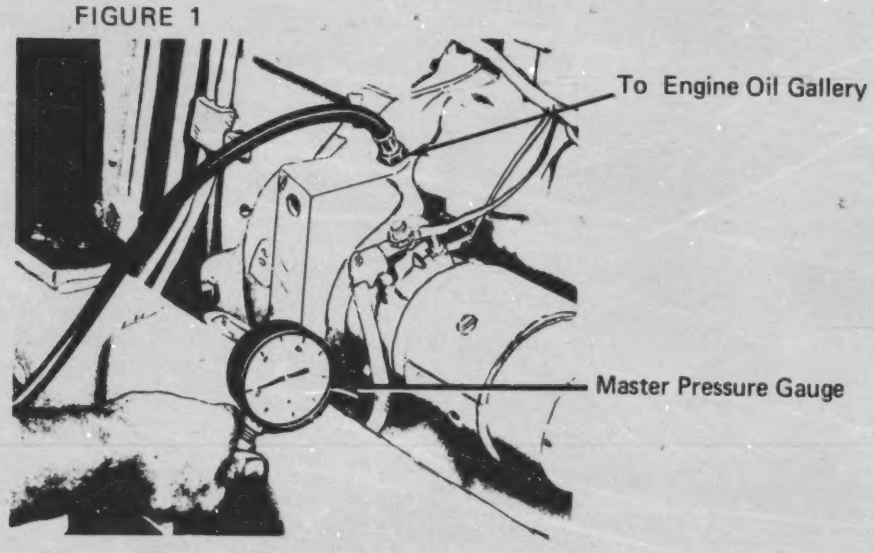
F Safety glasses

II. Pressure

A. Check condition of oil filter, replace if dirty

B. Install a master gauge (Figure 1)

FIGURE 1



C. Start engine and warm up at fast idle speed

D. Record pressure reading on the gauge

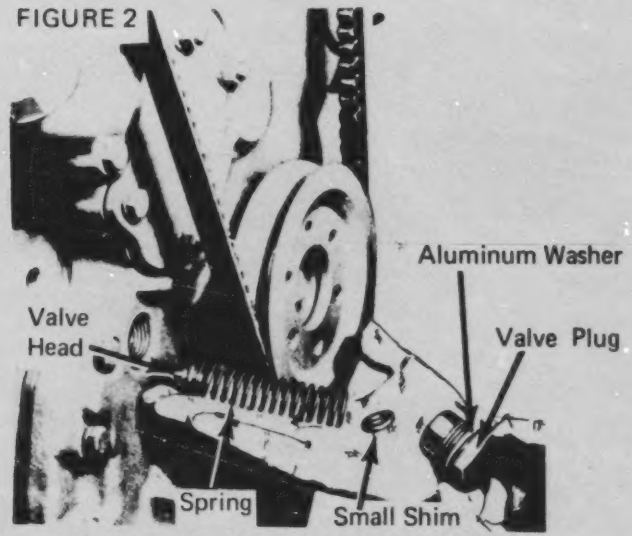
E. Compare reading with the engine specifications

JOB SHEET #1

F. Adjust pressure regulating valve

1. Adjust pressure regulating valve with shims (Figure 2)

FIGURE 2

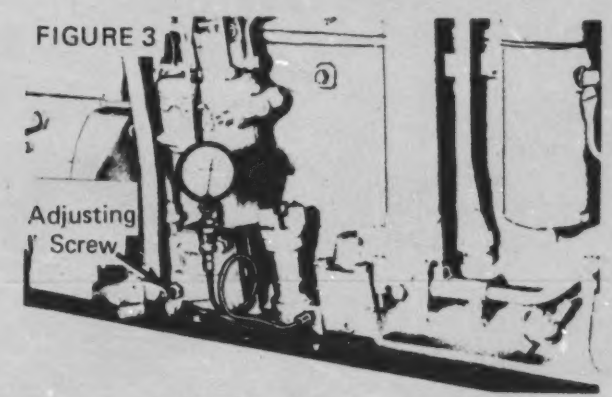


a. Raise pressure by adding shims

b. Lower pressure by removing shims

2. Adjust pressure regulating valve with screw (Figure 3)

FIGURE 3



a. Raise pressure by turning screw in

b. Lower pressure by turning screw out

LUBRICATION SYSTEM
UNIT I

NAME_____

TEST

1. Match the terms on the right to the correct definitions.

_____a.	American Petroleum Institute	1.	Viscosity
_____b.	Resistance to movement between any two objects placed in contact with each other	2.	Gallery
		3.	Friction
_____c.	Society of Automotive Engineers	4.	API
_____d.	Measure of an oil's ability to flow	5.	SAE
_____e.	Pipe or passageway in the engine used to carry engine oil from one area to another		

2. List five functions of the lubrication system.

a.

b.

c.

d.

e.

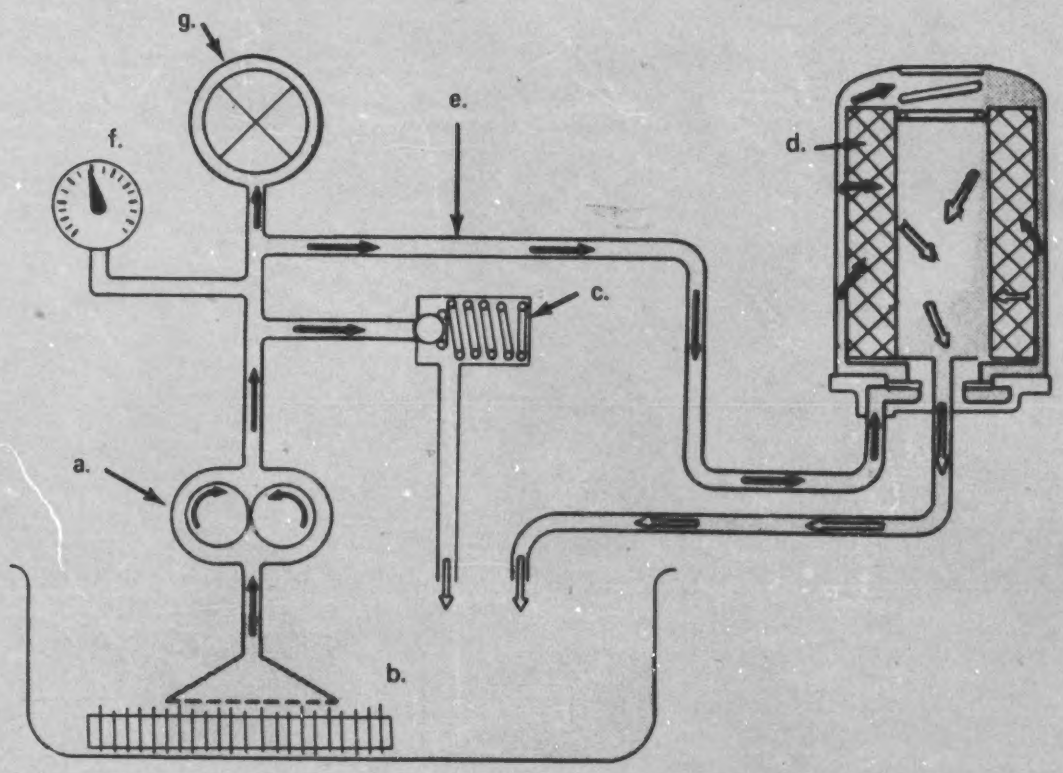
3. List three types of lubrication systems.

a.

b.

c.

4. Identify the components of the lubrication system.



a. _____ e. _____

b. _____ f. _____

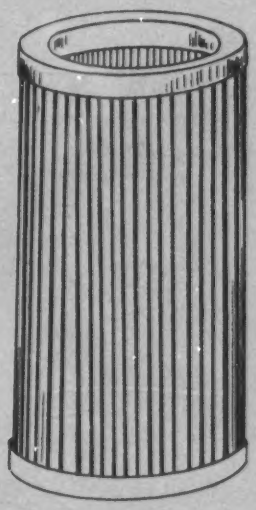
c. _____ g. _____

d. _____

5. Match the components of the lubrication system on the right to their purposes.

_____a. Provides a reservoir for the engine oil	1. Oil galleries
_____b. Limits the maximum oil pressure	2. Oil filter
_____c. Carry engine oil from one area to another	3. Pressure regulating valve
_____d. Indicates oil pressure during engine operation	4. Oil pump
	5. Oil pan
_____e. Forces oil under pressure to various parts of the engine for lubrication	6. Pressure gauge
_____f. Strains the engine oil removing abrasive particles	7. Oil cooler
_____g. Engine coolant flows through this and helps dissipate the heat in the engine oil	

6. Identify two types of oil filters.



a. _____ b. _____

7. Name two types of oil pumps.

a.

b.

8. List five sources of oil contamination.

   a.

   b.

   c.

   d.

   e.

9. List the purposes of lubricating valves.

   a.

   b.

10. Discuss the water and oil circulation in an oil cooler.

11. Discuss two types of oil pressure indicating systems.

12. Demonstrate the ability to check and adjust oil pressure on a live engine.

    (NOTE: If this activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

LUBRICATION SYSTEMS
UNIT I

ANSWERS TO TEST

1. a. 4
   b. 3
   c. 5
   d. 1
   e. 2

2. a. Reduces friction between moving parts
   b. Absorbs and dissipates heat
   c. Seals the piston rings and cylinder walls
   d. Cleans and flushes moving parts
   e. Helps deaden the noise of the engine

3. a. Circulating splash
   b. Internal force feed and splash
   c. Full internal force feed

4. a. Oil pump
   b. Oil pan
   c. Pressure regulating valve
   d. Oil filter
   e. Oil galleries
   f. Pressure gauge
   g. Engine bearings

5. a. 5
   b. 3
   c. 1
   d. 6
   e. 4
   f. 2
   g. 7

6. a. Depth filter - cotton waste type
   b. Surface filter - wire mesh type
7. Any two of the following:
   a. Gear
   b. Rotor
   c. Vane
8. Any five of the following:
   a. Storing and handling
   b. Dust from air that is breathed into engine
   c. Improper engine warm-up
   d. Antifreeze leaking into oil supply
   e. Oxidation
   f. Carbon particles
   g. Engine wear
   h. Fuel dilution
9. a. Regulate oil pressure
   b. Bypass oil at filters and oil coolers
10. Discussion should include:
   a. Internally mounted--Engine coolant is pumped by water pump through oil cooler mounted in the crankcase and back to the radiator where the heat is dissipated
   b. Externally mounted--Both water and oil are pumped through the oil cooler
11. Discussion should include:
   a. Mechanical--Bourdon tube gauge which tends to straighten out when pressure is applied
   b. Electrical
      1) Sending unit is at pressure source
      2) Indicating gauge is on control panel
12. Performance skills evaluated to the satisfaction of the instructor

COOLING SYSTEMS
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to list the effects of an engine running too hot or too cold. The student should also be able to name two functions of the cooling system and identify the parts in a liquid cooling system. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with the cooling system to the correct definitions.
2. Name two functions of the cooling system.
3. List effects of an engine running too hot.
4. List effects of an engine running too cold.
5. Identify the parts in a liquid cooling system.
6. Identify two types of radiators.
7. Name two functions of the radiator cap.
8. Name three types of fans used in cooling systems.
9. Name types of fan control.
10. List three purposes for using a coolant filter or conditioner in the cooling system.
11. Select functions of the thermostat.
12. Select types of thermostats.
13. Match the disadvantages of using water as a coolant to the corrective actions.
14. Select common materials that may restrict radiator coolant flow.
15. Identify the primary parts of a water pump and fan.

16. Demonstrate the ability to:

a. Reverse flush a radiator.

b. Test thermostat action.

c. Test for exhaust gas leakage and air in cooling system.

COOLING SYSTEMS
UNIT II

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined in the job sheets.

G. Demonstrate water pump overhaul.

H. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete job sheets.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Parts in a Liquid Cooling System
2. TM 2--Types of Radiators
3. TM 3--Pressure Cap Operation

4. TM 4--Fan Types

5. TM 5--Coolant Filter

6. TM 6--Operation of a Thermostat

7. TM 7--Types of Thermostats

8. TM 8--Water Pump and Fan

D. Job Sheets

1. Job Sheet #1--Reverse Flush a Radiator

2. Job Sheet #2--Test Thermostat Action

3. Job Sheet #3--Test for Exhaust Gas Leakage and Air in Cooling System

E. Test

F. Answers to test

II. References:

A. *Fundamentals of Service: Engines.* Moline, Illinois: Deere and Company, 1972.

B. Kates, Edgar J. and Luck, William E. *Diesel and High Compression Gas Engines.* 3rd ed. Chicago: American Technical Society, 1972.

COOLING SYSTEMS
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Coolant--Liquid that circulates through the cooling system to transfer engine heat

B. Thermostat--Heat operated valve that automatically maintains correct operating temperature

C. Pressure cap--Radiator cap with pressure and vacuum valve

D. Fan--Forces cooling air through radiator core to more quickly dissipate the heat

E. Bimetallic--Two strips of dissimilar metal welded together, one of which expands more when heated than the other

F. Inhibitor--Chemical which dissolves in water to form a rustproof film on the metal

G. Aeration--Mixture of air and water

H. Radiator shutters--Device over radiator to maintain temperature variations of coolant

I. Radiator--Heat exchanger in which cooling water gives up heat to the air without coming into direct contact with it

II. Functions of the cooling system

A. Prevents engine overheating

B. Regulates engine temperature

III. Effects of an engine running too hot

A. Excessive wear

B. Scoring

C. Knock

D. Burned piston and valves

E. Lubrication failure

F. Seizure of moving parts

G. Loss of power

INFORMATION SHEET

IV. Effects of an engine running too cold

- A. Excessive wear
- B. Poor fuel economy
- C. Accumulation of water and sludge in the crankcase
- D. Loss of power

V. Parts in a liquid cooling system (Transparency 1)

- A. Radiator
- B. Fan drive belt
- C. Water pump
- D. Engine water jacket
- E. Thermostat
- F. Connecting hoses
- G. Liquid or coolant
- H. Pressure cap
- I. Bypass
- J. Fan
- K. Shutters and control

VI. Types of radiators (Transparency 2)

- A. Cellular type core
- B. Tube and fin type core

VII. Functions of the radiator cap (Transparency 3)

- A. Allows atmospheric pressure to enter the cooling system

  (NOTE: The vacuum valve opens.)

- B. Prevents coolant from escaping at normal temperatures

  (NOTE: The pressure valve permits escape of coolant or steam when pressure reaches a certain point. Pressure rise of one pound will raise the boiling temperature of water about 3 degrees fahrenheit.)

INFORMATION SHEET

VIII. Types of fans used in cooling systems (Transparency 4)

A. Suction type

B. Blower type

C. Reversible type

IX. Types of fan control

A. Helical coil spring

B. Flex-blade fan

C. Electric auxillary control

X. Purposes of a coolant filter or conditioner (Transparency 5)

A. Softens the water

(NOTE: Chemicals in the filter element remove corrosives and keep the water jackets free of scale.)

B. Removes dirt

(NOTE: Filter element is replaceable and dirt which settles to bottom may be drained.)

C. Provides a place for rust inhibitors in the filter element

(NOTE: Rust inhibitors dissolve to form a rust proof film on the metal surfaces of the cooling system.)

XI. Functions of the thermostat (Transparency 6)

A. Provides automatic control of the engine temperature

B. Permits rapid engine warm-up when closed

C. Permits efficient cooling when open

XII. Types of thermostats (Transparency 7)

A. Bellows

B. Bimetallic

C. Pellet

INFORMATION SHEET

XIII. Disadvantages of using water as a coolant and corrective actions

A. Freezes readily when cold--Add antifreeze

B. Boils and evaporates when hot--Pressurize system

C. Corrodes metal parts--Add rust inhibitor

D. Causes mineral deposits and scale in water jackets--Use soft water and chemical additives

XIV. Materials that may restrict radiator coolant flow

A. Rust

B. Scale

C. Oil

D. Lime

XV. Primary parts of a water pump and fan (Transparency 8)

A. Fan blade assembly

B. Fan hub

C. Fan belt

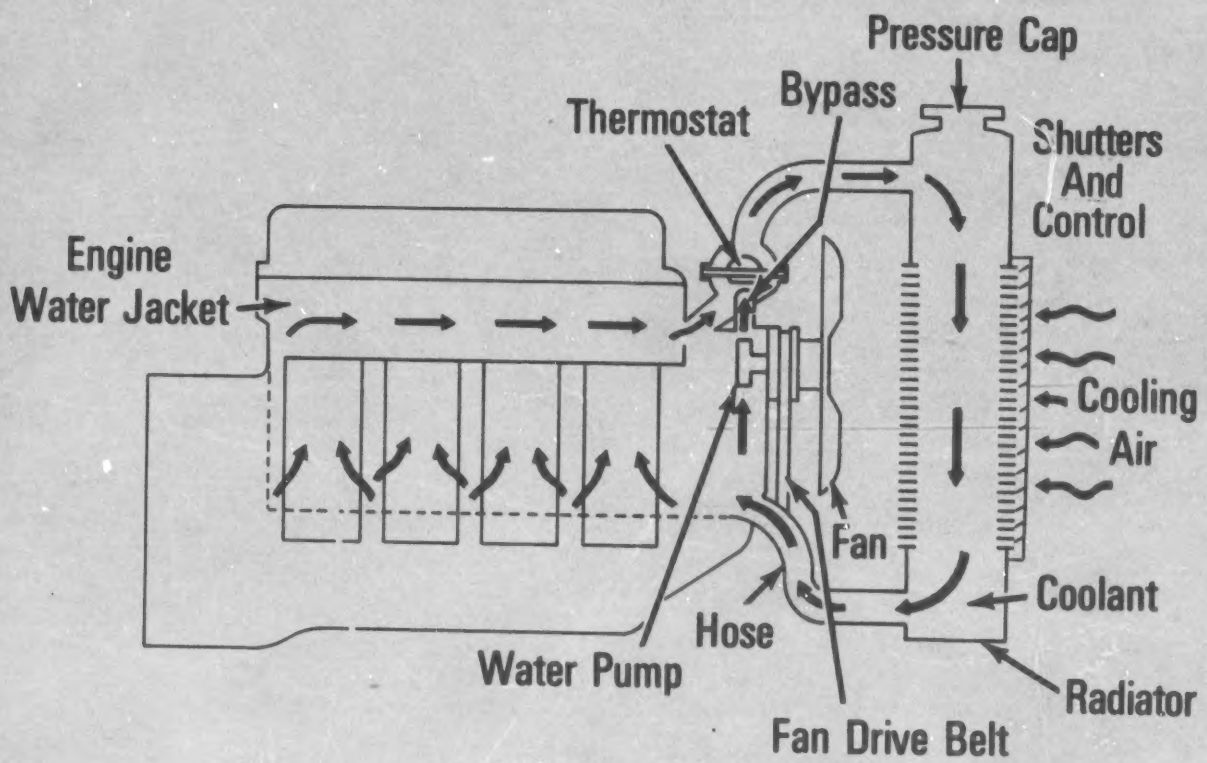
D. Pulley

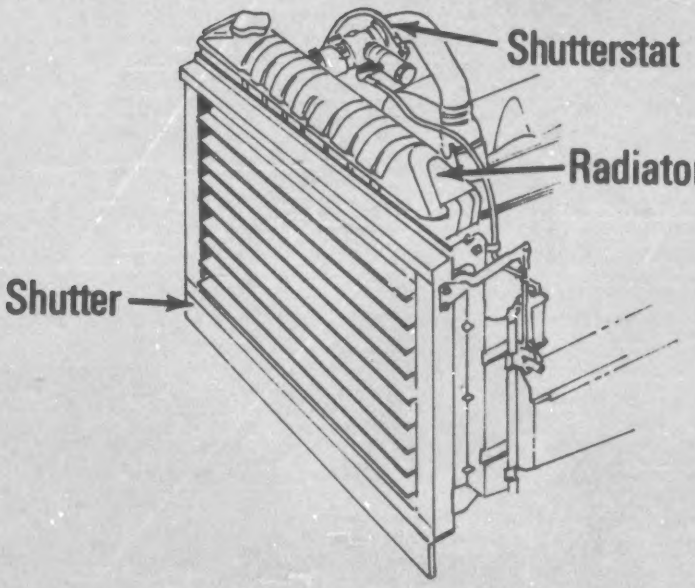
E. Bearing and shaft assembly

F. Water pump housing

G. Impeller

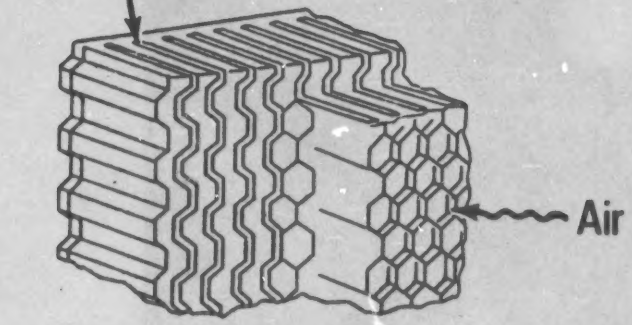
Parts In a Liquid Cooling System



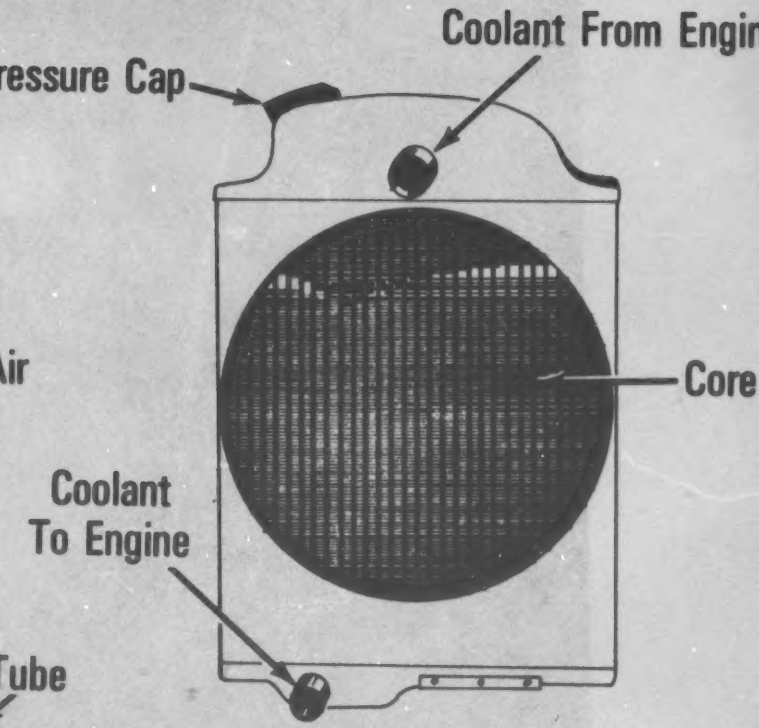


Typical Air Operated Shutter Assembly

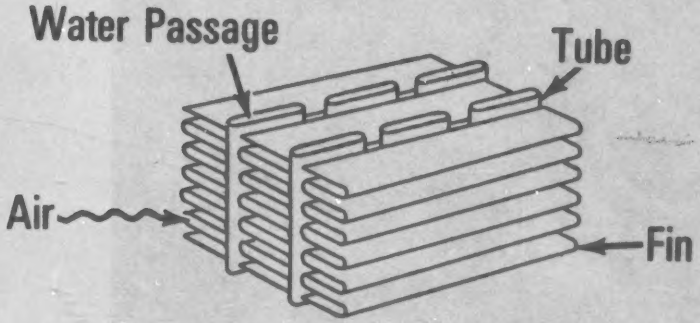
Types of Radiators



Cellular Type Core Radiator

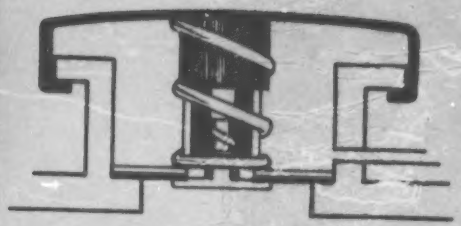


Typical Radiator



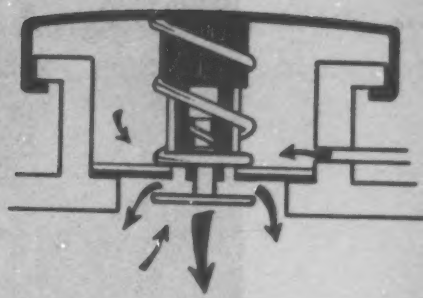
Tube and Fin-Type Core Radiator

Pressure Cap Operation



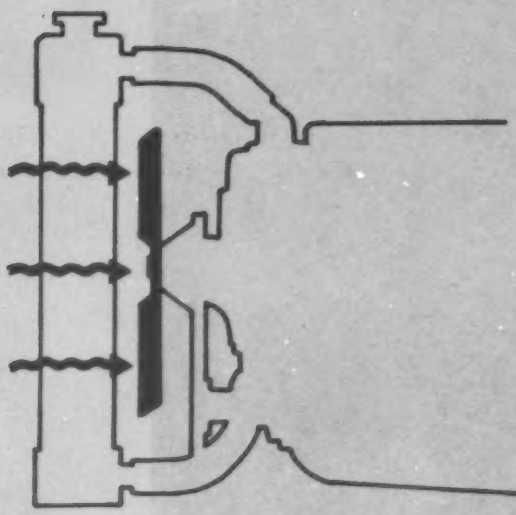
Valves Closed

Pressure Valve Open

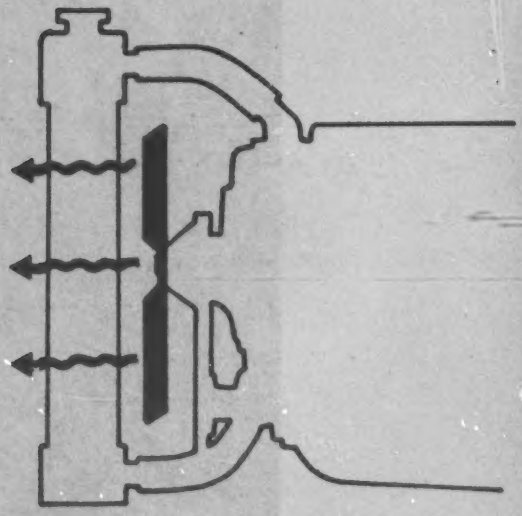


Vacuum Valve Open

Fan Types

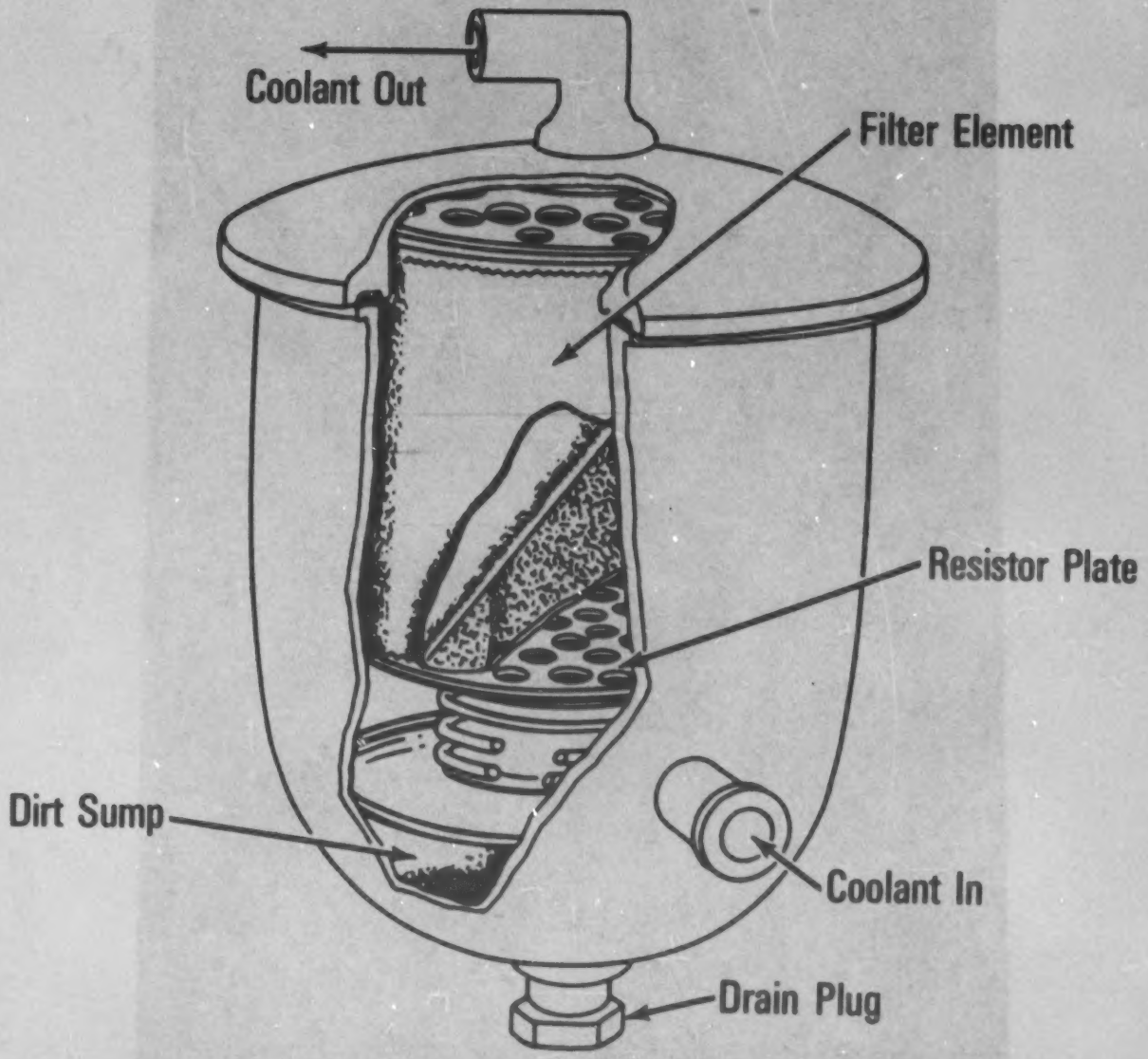


Suction Fan

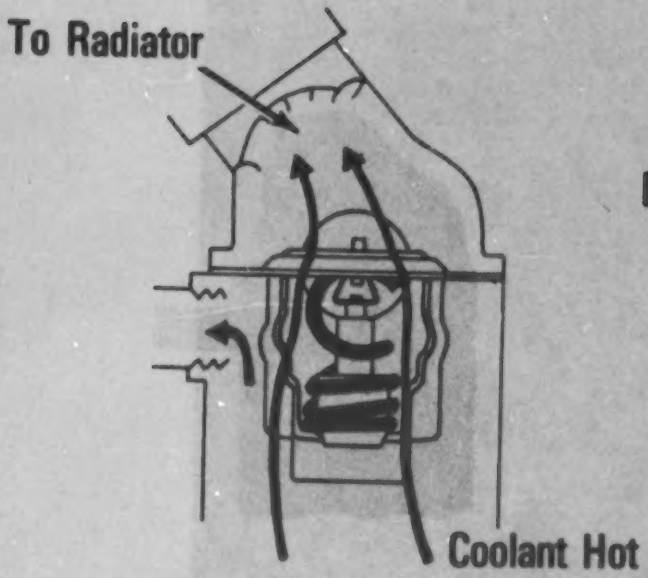


Blower Fan

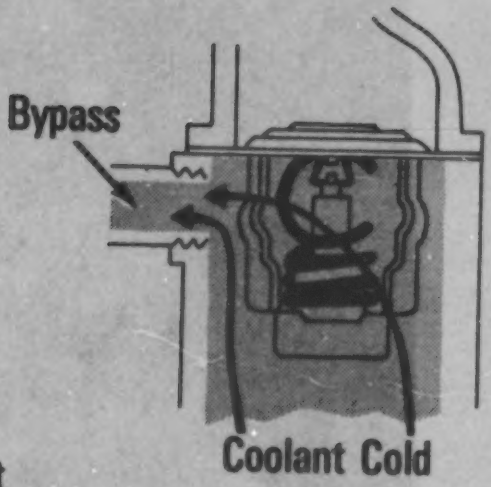
Coolant Filter



Operation of a Thermostat

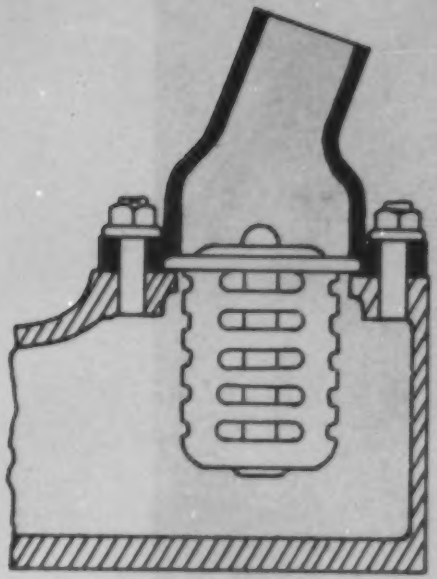


Thermostat Open

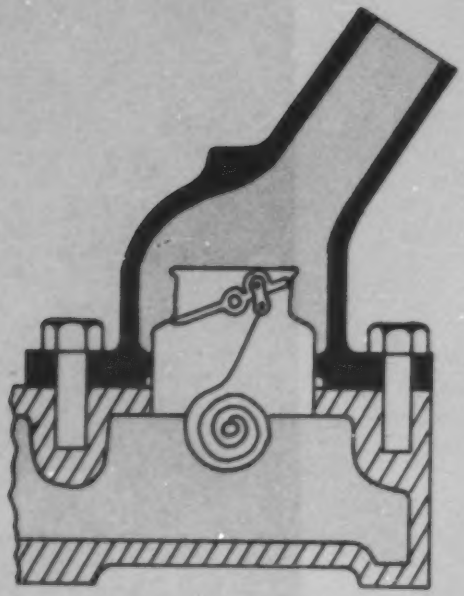


Thermostat Closed

Types of Thermostats

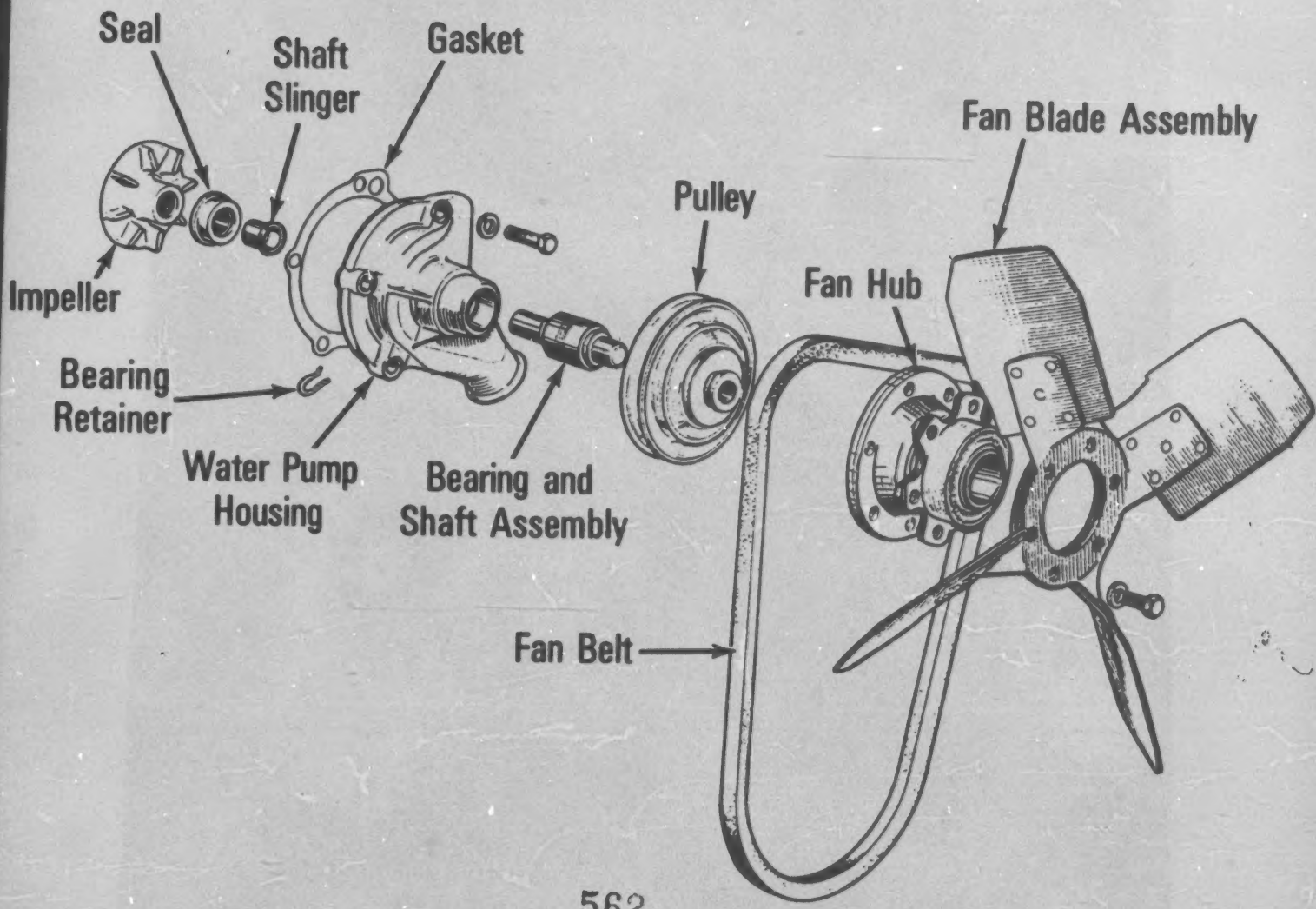


Bellows Thermostat



Bimetallic Thermostat

Water Pump and Fan



COOLING SYSTEM
UNIT II

JOB SHEET #1--REVERSE FLUSH A RADIATOR

I. Tools and materials

A. Flushing gun

B. Hand tools

C. Water source

D. Compressed air source

E. Safety glasses

II. Procedure

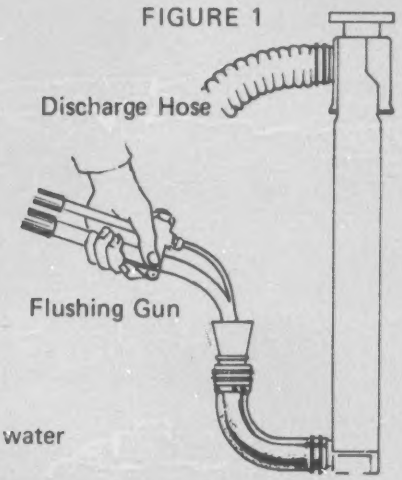
A. Drain the radiator

B. Disconnect both hoses

C. Connect the flushing gun hose to water source and air source of 100 PSI (pounds per square inch)

D. Connect the flushing gun nozzle to lower radiator hose (Figure 1)

FIGURE 1



E. Turn on water

F. Fill radiator

G. Inject air in short bursts to clear the tubes

H. Allow radiator to fill between bursts

I. Continue until water flows freely

COOLING SYSTEM
UNIT II

JOB SHEET #2--TEST THERMOSTAT ACTION

I. Tools and materials

A. Heat source

B. Container of water

C. Thermometer

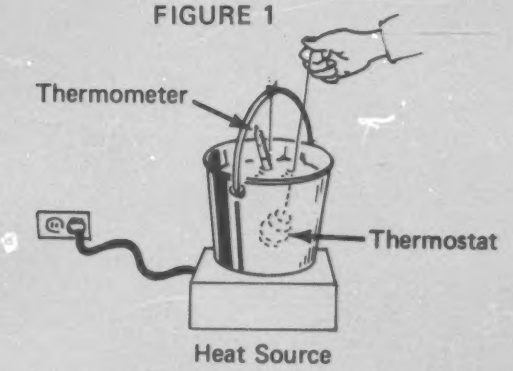
D. Thermostat

E. Safety glasses

II. Procedure

A. Suspend the thermostat and thermometer in container of water (Figure 1)

FIGURE 1



B. Compare the temperature rating stamped on the frame of thermostat to the thermometer

C. Thermostat should start to open at the temperature stamped on the frame and be fully open at 22°F above the specified temperature

D. Remove thermostat and observe its closing action

E. If thermostat is defective, discard

COOLING SYSTEMS
UNIT II

JOB SHEET #3--TEST FOR EXHAUST GAS LEAKAGE AND AIR IN COOLING SYSTEM

I. Tools and materials

A. Live engine

B. Rubber tube

C. Bottle of water

D. Safety glasses

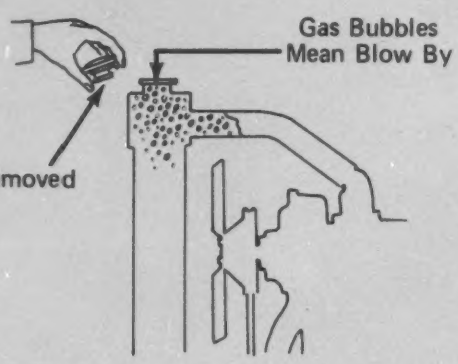
II. Procedure

A. Test for exhaust gas leakage (blow-by)

1. Warm up the engine and keep it under load

2. Remove the radiator cap and look for excessive bubbles in the coolant (Figure 1)

FIGURE 1



3. Look for a sign of blow-by such as bubbling or an oil film on the coolant

(NOTE: A cracked head or a loose cylinder head joint allows hot exhaust gas to be blown into the cooling system under combustion pressures; even though the joint may be tight enough to keep liquid from leaking into the cylinder. The cylinder head gasket itself may be burned and corroded by escaping exhaust gases. Exhaust gases dissolved in coolant destroy the inhibitors and form acids which cause corrosion, rust, and clogging.)

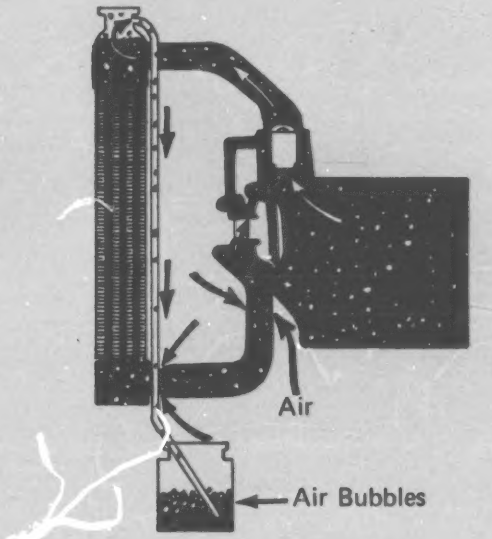
JOB SHEET #3

B. Test for air in cooling system

1. Adjust coolant to correct level
2. Replace pressure cap with a plain, air-tight cap
3. Attach rubber tube to lower end of overflow pipe

   (NOTE: Be sure radiator cap and tube are air tight.)
4. With transmission in neutral gear, run engine at high speed until temperature gauge stops rising and remains stationary
5. Without changing engine speed or temperature, put end of rubber tube in bottle of water
6. Watch for continuous stream of bubbles in the water bottle, showing that air is being drawn into the cooling system (Figure 2)

FIGURE 2



(NOTE: Air may be drawn into the coolant because of a leak in the system, turbulence in the top tank, or too-low coolant level.)

COOLING SYSTEMS
UNIT II

NAME _____

TEST

1. Match the terms on the right to the correct definitions.

_____a. Liquid that circulates through the cooling system to transfer engine heat

_____b. Heat operated valve that automatically maintains correct operating temperature

_____c. Radiator cap with pressure and vacuum valve

_____d. Forces air through radiator core to more quickly dissipate the heat

_____e. Two strips of dissimilar metal welded together, one of which expands more when heated than the other

_____f. Chemical which dissolves in water to form a rustproof film on the metal

_____g. Mixture of air and water

_____h. Device over radiator to maintain temperature variations of coolant

_____i. Heat exchanger in which cooling water gives up heat to the air without coming into direct contact with it

1. Inhibitor
2. Bimetallic
3. Radiator
4. Pressure cap
5. Coolant
6. Aeration
7. Thermostat
8. Radiator shutters
9. Fan

2. Name two functions of the cooling system.

a.

b.

3. List four effects of an engine running too hot.

a.

b.

c.

d.

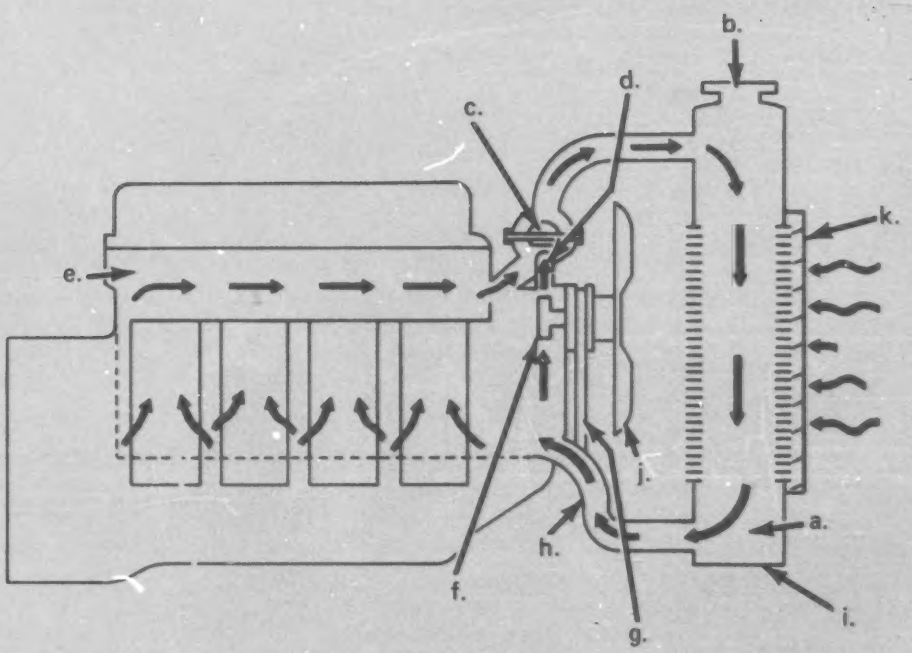
4. List three effects of an engine running too cold.

   a.

   b.

   c.

5. Identify the parts in a liquid cooling system.



a. _____ g. _____

b. _____ h. _____

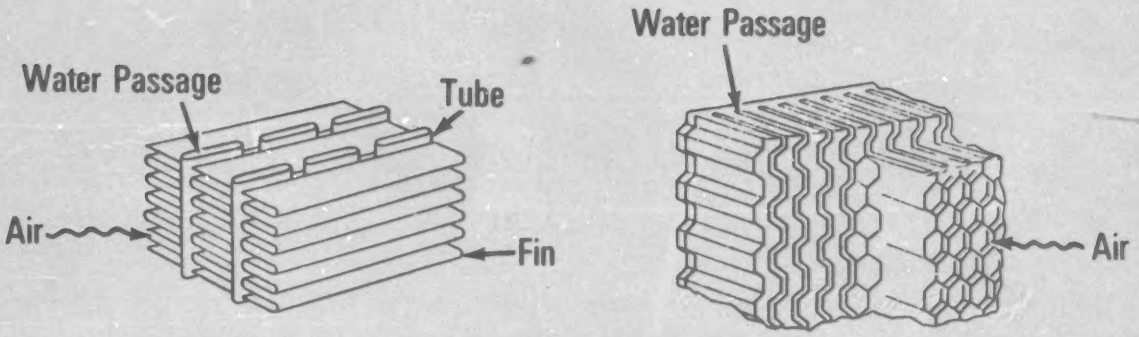
c. _____ i. _____

d. _____ j. _____

e. _____ k. _____

f. _____

6. Identify two types of radiators.



a. _____ b. _____

7. Name two functions of the radiator cap.

a.

b.

8. Name three types of fans used in cooling systems.

a.

b.

c.

9. Name two types of fan control.

a.

b.

10. List three purposes for using a coolant filter or conditioner in the cooling system.

a.

b.

c.

11. Select functions of the thermostat by placing an "X" in the appropriate blanks.

_____a. Permits rapid engine warm-up when closed

_____b. Permits efficient cooling when open

_____c. Permits rapid engine warm-up when open

_____d. Permits efficient cooling when closed

_____e. Provides automatic control of the engine temperature

12. Select the types of thermostats by placing an "X" in the appropriate blanks.

_____a. Burrows

_____b. Rectangular

_____c. Bellows

_____d. Bimetallic

_____e. Pellet

13. Match the corrective actions on the right to the disadvantages of using water as a coolant.

_____a. Freezes readily when cold

_____b. Causes mineral deposits and scale in water jackets

_____c. Boils and evaporates when hot

_____d. Corrodes metal parts

1. Add rust inhibitor
2. Add antifreeze
3. Pressurize system
4. Use soft water and chemical additives

14. Select common materials that may restrict radiator coolant flow by placing an "X" in the appropriate blanks.

_____a. Oil

_____b. Hair

_____c. Suds

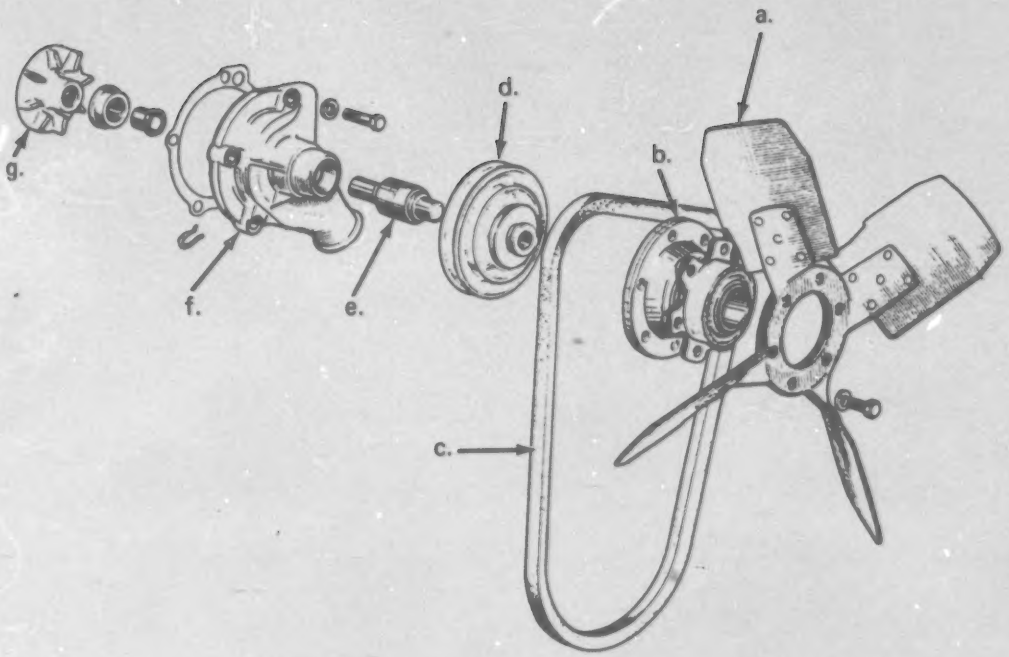
_____d. Lime

_____e. Scale

_____f. Mud

_____g. Rust

15. Identify the primary parts of a water pump and fan.



a. _____

b. _____

c. _____

d. _____

e. _____

f. _____

g. _____

16. Demonstrate the ability to:

    a. Reverse flush a radiator.

    b. Test thermostat action.

    c. Test for exhaust gas leakage and air in cooling system.

    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

COOLING SYSTEMS
UNIT II

ANSWERS TO TEST

1. a. 5 e. 2 i. 3
   b. 7 f. 1
   c. 4 g. 6
   d. 9 h. 8
2. a. Prevents engine overheating
   b. Regulates engine temperature
3. Any four of the following:
   a. Excessive wear
   b. Scoring
   c. Knock
   d. Burned piston and valves
   e. Lubrication failure
   f. Seizure of moving parts
   g. Loss of power
4. Any three of the following:
   a. Excessive wear
   b. Poor fuel economy
   c. Accumulation of water and sludge in the crankcase
   d. Loss of power
5. a. Liquid or coolant
   b. Pressure cap
   c. Thermostat
   d. Bypass
   e. Engine water jacket

f. Water pump

g. Fan drive belt

h. Connecting hoses

i. Radiator

j. Fan

k. Shutters and control

6. a. Tube and fin type core radiator

b. Cellular type core radiator

7. a. Allows atmospheric pressure to enter the cooling system

b. Prevents coolant from escaping at normal temperatures

8. a. Suction type

b. Blower type

c. Reversible type

9. Any two of the following:

a. Helical coil spring

b. Flex-blade fan

c. Electric auxillary control

10. a. Softens the water

b. Removes dirt

c. Provides a place for rust inhibitors in the filter element

11. a, b, e

12. c, d, e

13. a. 2

b. 4

c. 3

d. 1

14. a, d, e, g

15. a. Fan blade assembly

    b. Fan hub

    c. Fan belt

    d. Pulley

    e. Bearing and shaft assembly

    f. Water pump housing

    g. Impeller

16. Performance skills evaluated to the satisfaction of the instructor

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify the components of an air intake and exhaust system. The student should also be able to disassemble, service, repair, and assemble a supercharger. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with air intake and exhaust systems to the correct definitions.
2. Name parts of an air intake system.
3. Name parts of an exhaust system.
4. Discuss three types of air cleaners.
5. Discuss three methods of scavenging the cylinders on a two-stroke cycle engine.
6. Distinguish between port scavenging and valve scavenging in two-cycle engines.
7. Discuss two types of superchargers.
8. List advantages of a turbocharged engine.
9. Demonstrate the ability to:
   a. Test an engine for air flow restriction.
   b. Inspect a turbocharger for satisfactory operation.
   c. Remove, disassemble, service, assemble, and install a turbocharger.
   d. Disassemble, service, repair, and assemble a supercharger.

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III

SUGGESTED ACTIVITIES

I. Instructor:

- A. Provide student with objective sheet.
- B. Provide student with information and job sheets.
- C. Make transparencies.
- D. Discuss unit and specific objectives.
- E. Discuss information sheet.
- F. Demonstrate and discuss the procedures outlined in the job sheets.
- G. Give test.

II. Student:

- A. Read objective sheet.
- B. Study information sheet.
- C. Complete job sheets.
- D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
  1. TM 1--Dry Type Air Cleaner
  2. TM 2--Viscous-Impingement Air Cleaner
  3. TM 3--Oil Bath Air Cleaner
  4. TM 4--Crankcase Scavenging Engine
  5. TM 5--Scavenging Pump and Blower
  6. TM 6--Port-Scavenged Engine

7. TM 7--Valve-Scavenged Engine

8. TM 8--Positive Displacement Supercharger

9. TM 9--Centrifugal Type Supercharger

D. Job sheets

1. Job Sheet #1--Test An Engine for Air Flow Restriction

2. Job Sheet #2--Inspect a Turbocharger for Satisfactory Operation

3. Job Sheet #3--Remove, Disassemble, Service, Assemble, and Install a Turbocharger

4. Job Sheet #4--Disassemble, Service, Repair, and Assemble a Supercharger

E. Test

F. Answers to test

II. References:

A. Kates, Edgar J., and Luck, William E. *Diesel and High Compression Gas Engines.* 3rd ed. Chicago: American Technical Society, 1972.

B. *Fundamentals of Service: Engines.* Moline, Illinois: Deere and Company, 1972.

C. *V-71 Service Manual.* Detroit, Michigan: Detroit Diesel Allison, Revised 1975.

D. *H and NH Series Shop Manual.* Columbus, Indiana: Cummins Engine Co., Inc.

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III

INFORMATION SHEET

I. Terms and definitions

A. Filter--Unit containing an element of varying degrees of fineness to trap foreign particles

B. Scavenging--Method of pushing air out of the cylinders during the exhaust stroke on two-cycle engines

C. Port--Opening in a cylinder block or liner for intake and/or exhaust air on two-cycle engines

D. Valve--Device for sealing the intake and/or exhaust ports in a cylinder head

E. Blower--Method of increasing air pressure and velocity

F. Roots type blower--Positive displacement blower to raise intake air above atmospheric pressure

G. Turbocharger--Exhaust-driven turbine which drives a centrifugal compressor

H. Manifold--Pipe or casting with multiple openings to connect multiple cylinders to one outlet or inlet

I. Supercharging--Method of charging cylinders with fresh air above atmospheric pressure on the intake stroke

J. Naturally aspirated--Engine which is not supercharged

K. Precleaner--Device to collect some dirt from air before it enters the main air cleaner

II. Parts of an intake system

A. Precleaner, air cleaner

B. Supercharger (if used)

C. Intake manifold

D. Piping

E. Intake valves or ports

INFORMATION SHEET

III. Parts of an exhaust system

A. Ports and/or valves

B. Exhaust manifold

C. Piping

D. Muffler

E. Turbocharger (if used)

IV. Types of air cleaners

A. Dry element type--Cleaning is done by replacing element (Transparency 1)

B. Viscous-impingement type--Cleans air by passing it through a maze of metal wool, wire, or screens saturated with oil (Transparency 2)

C. Wet type--Cleans air by directing it through a center tube into the inner oil cup where direction of air flow is reversed causing most of the dirt to become trapped by the oil and settle in the sump (Transparency 3)

V. Methods of scavenging the cylinders

A. Crankcase (Transparency 4)

1. Air enters the engine through the crankcase

2. Each downward movement of the piston compresses the vapor within the crankcase until the intake port or valve opens

3. The compressed vapor escapes into the cylinder at a pressure nearly equal to atmospheric pressure

B. Power piston (Transparency 5)

1. Uses a separate piston and cylinder driven by the engine crankshaft

2. Pushes the vapor into the cylinder as the intake valve or port opens

C. Blower (Transparency 5)

1. Uses a positive-displacement rotary blower driven by the engine

2. Compresses the vapor into an air chamber surrounding the intake ports

INFORMATION SHEET

VI. Port and valve scavenging

A. Port scavenging--Air enters and gas leaves through ports in the cylinder block or liner which the piston uncovers (Transparency 6)

B. Valve scavenging--Air enters through ports in the cylinder block and gases leave through valves in the cylinder head (Transparency 7)

(NOTE: The scavenging process in the two-cycle engines uses a swish of air to push out the spent gases and replace them with fresh air at atmospheric pressure.)

VII. Types of superchargers

A. Positive displacement (Transparency 8)

(NOTE: The roots type blower is a positive-displacement supercharger.)

1. Driven by a chain, belt, or gear

2. Resembles oil pumps in design

B. Centrifugal (Transparency 9)

(NOTE: Turbochargers are an exhaust driven centrifugal type supercharger.)

1. Driven by engine, engine exhaust, or separate motor

2. Impeller normally moves thirty times engine speed

VIII. Advantages of a turbocharged engine

A. Increases horsepower output of a given displacement engine

B. Reduces weight by delivering more horsepower per pound than nonturbocharged engines

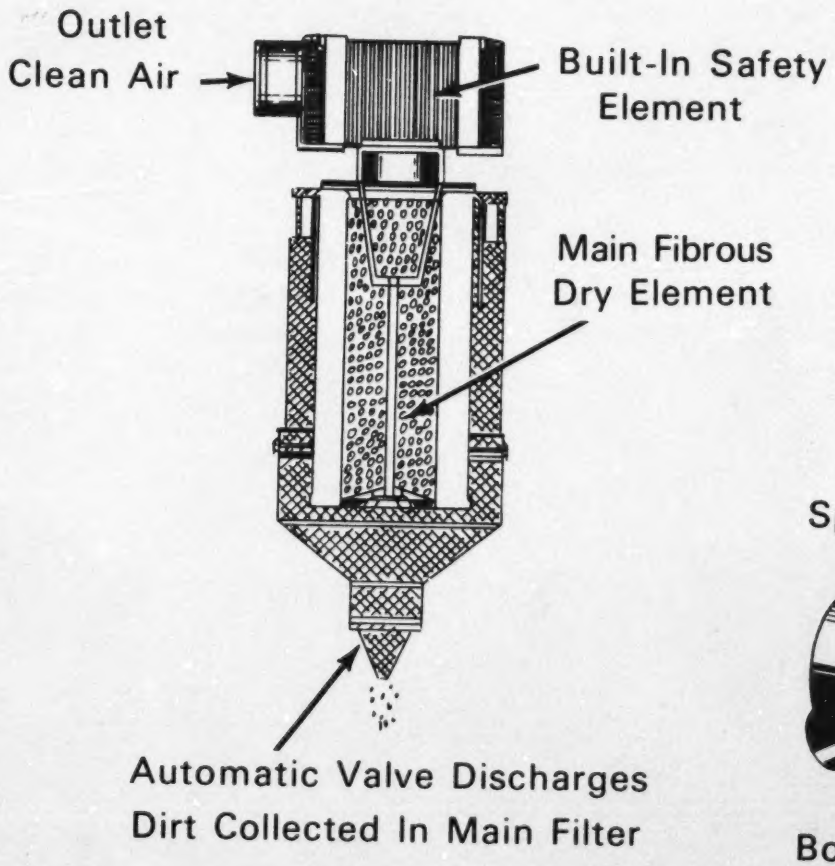
C. Cost of a turbocharged engine is less on a dollar per horsepower basis

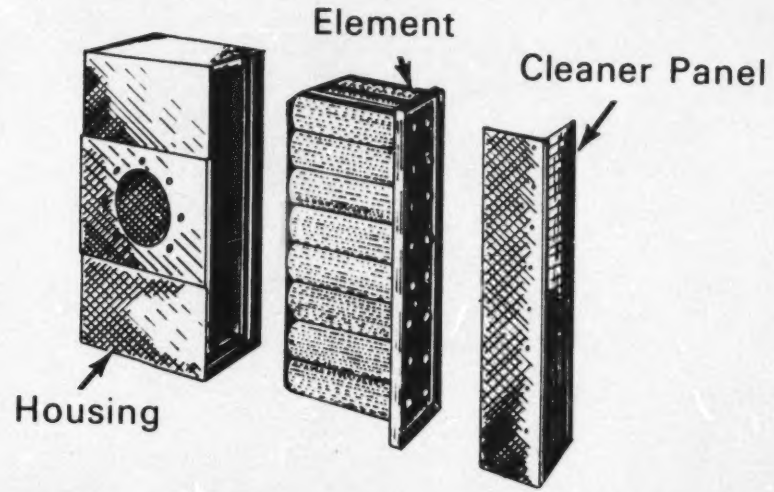
D. Maintains horsepower at higher altitudes

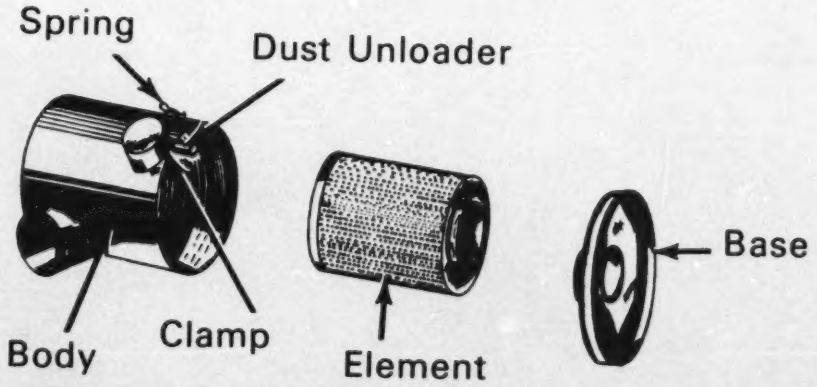
(NOTE: Naturally aspirated engines lose three percent of horsepower per each 1000 feet of altitude.)

E. Reduces exhaust smoke by supplying excess air to reduce exhaust density

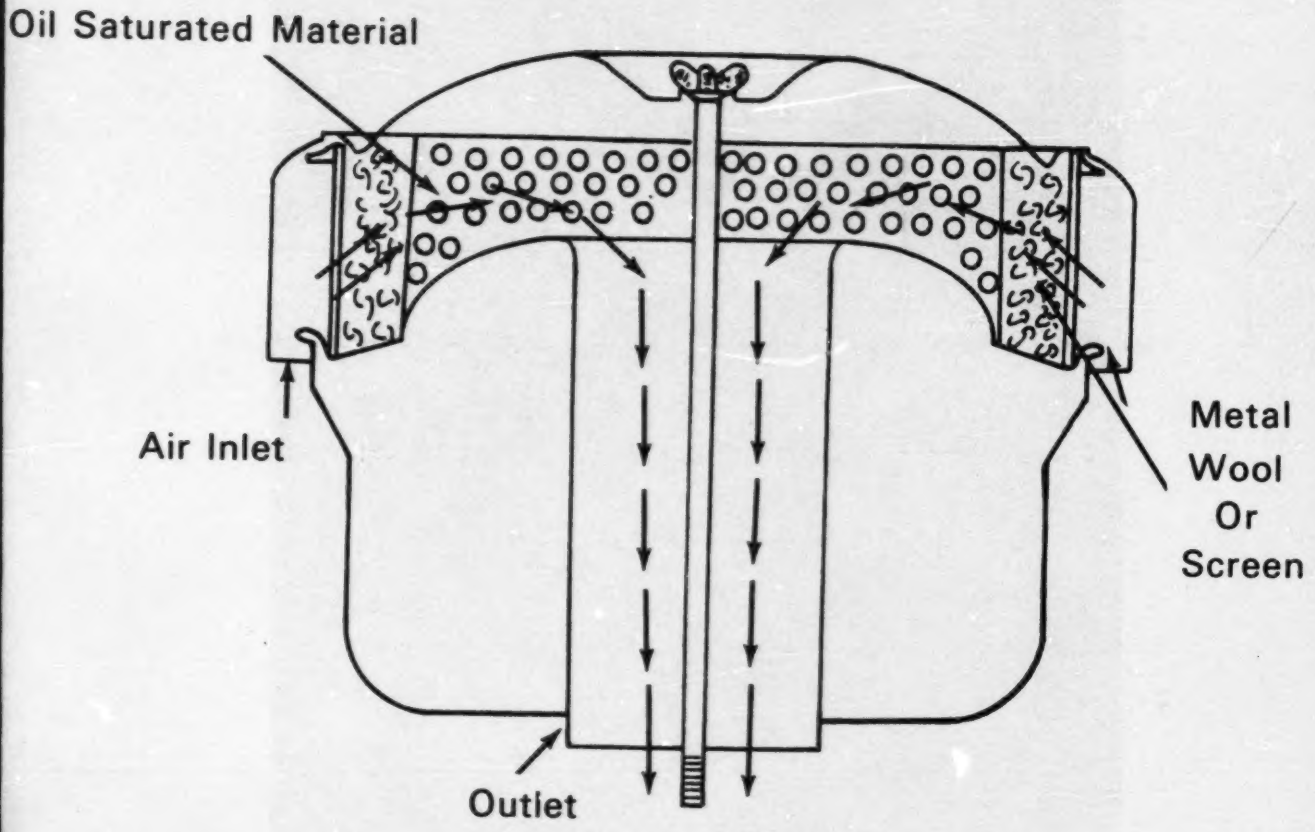
Dry Type Air Cleaner



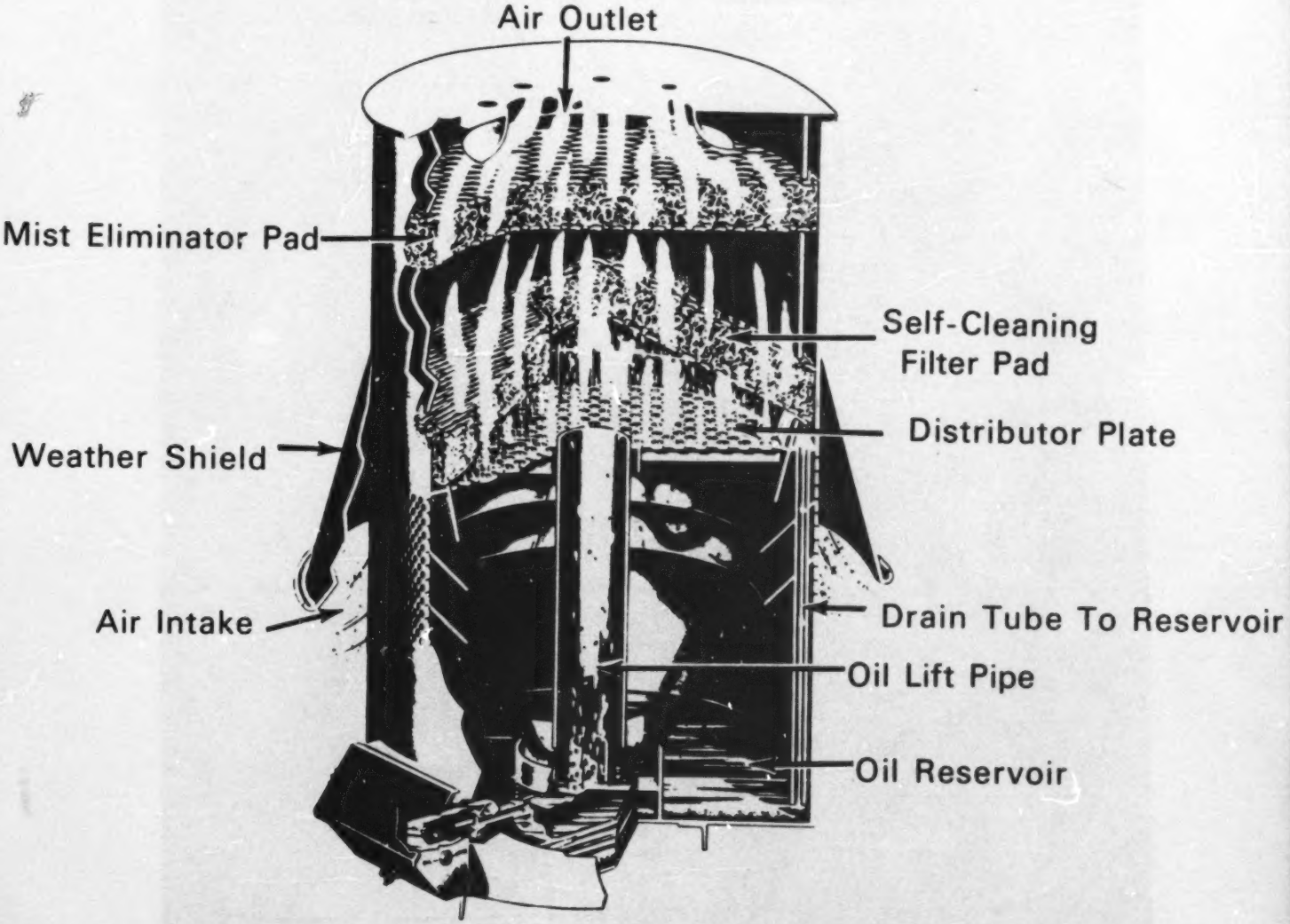




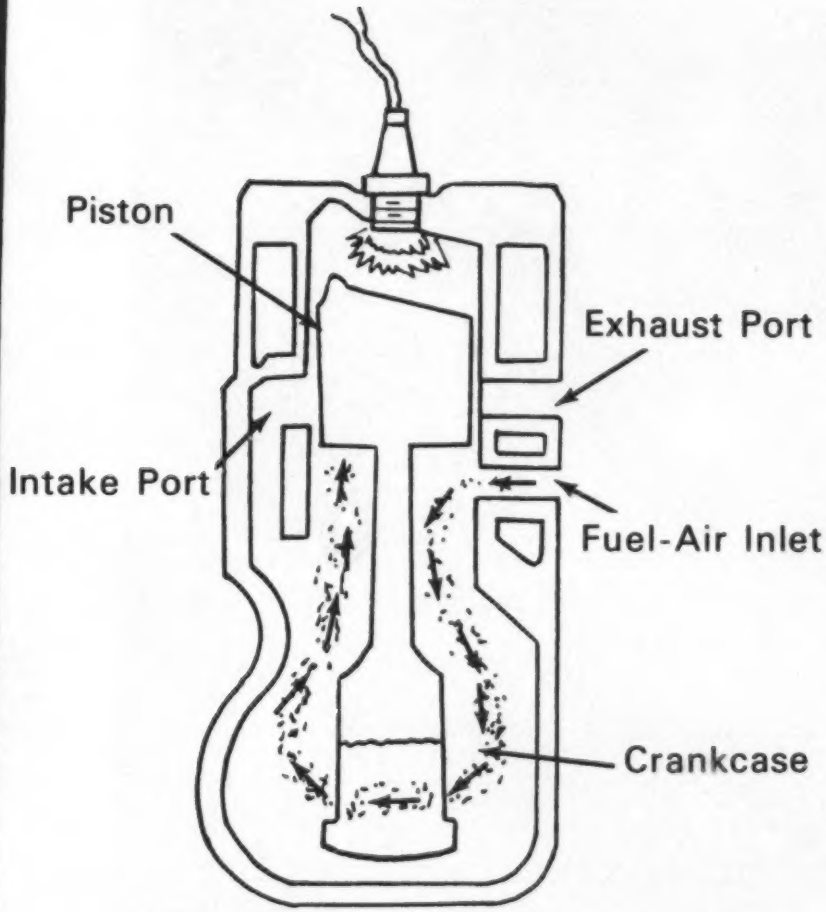
Viscous-Impingement Air Cleaner



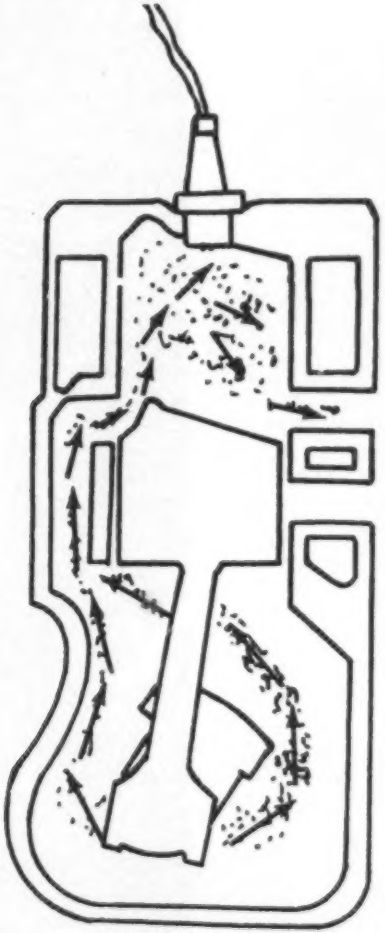
Oil Bath Air Cleaner



Crankcase Scavenging Engine

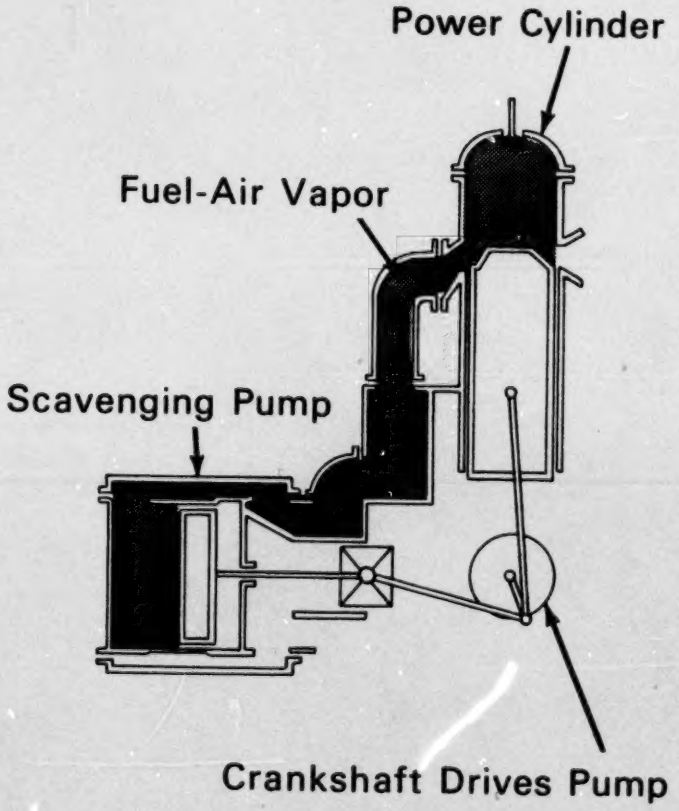


Compression/Power Stroke

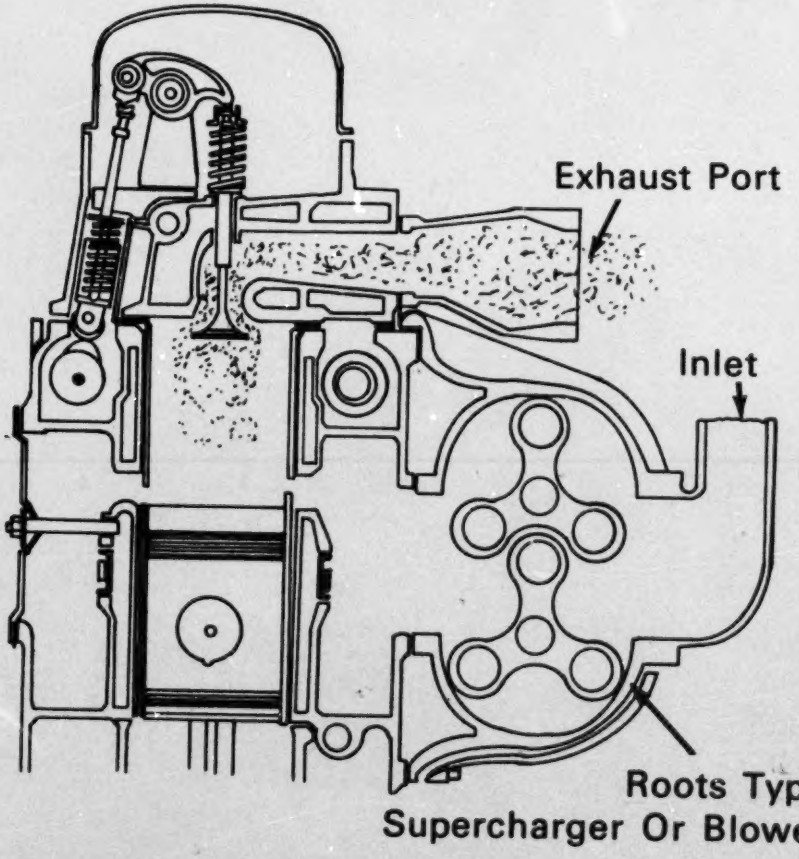


Intake/Exhaust Stroke

Scavenging Pump And Blower

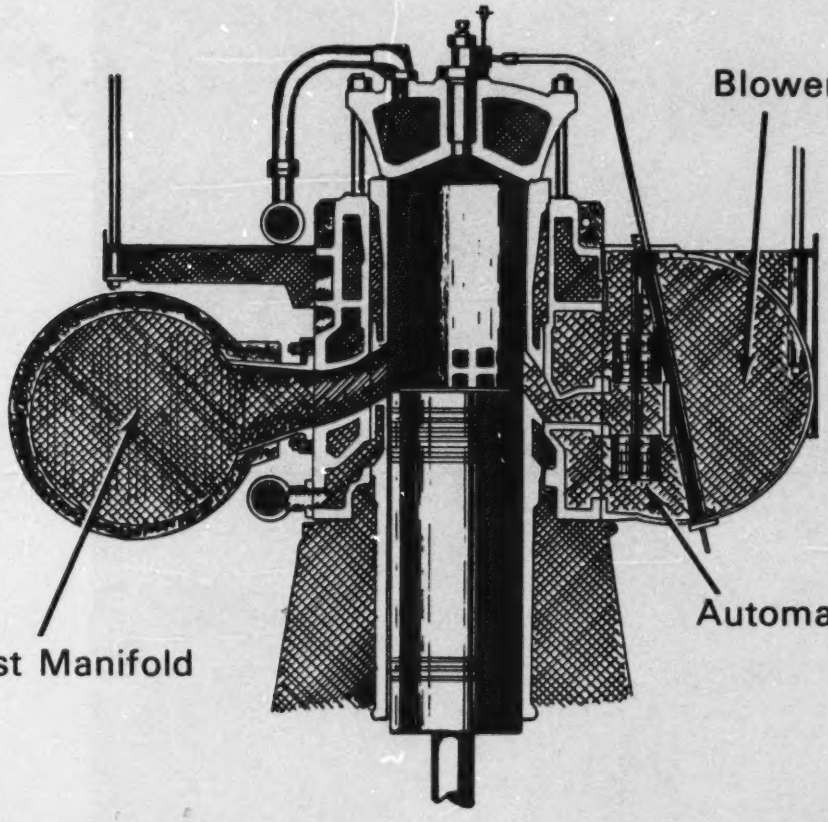


POWER PISTON

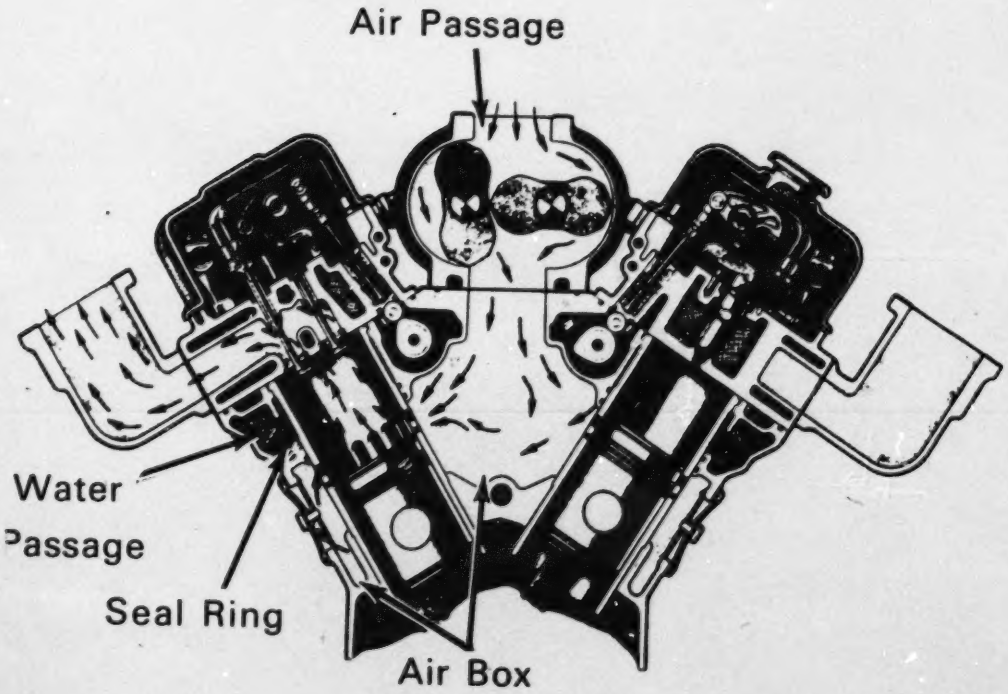


POSITIVE DISPLACEMENT

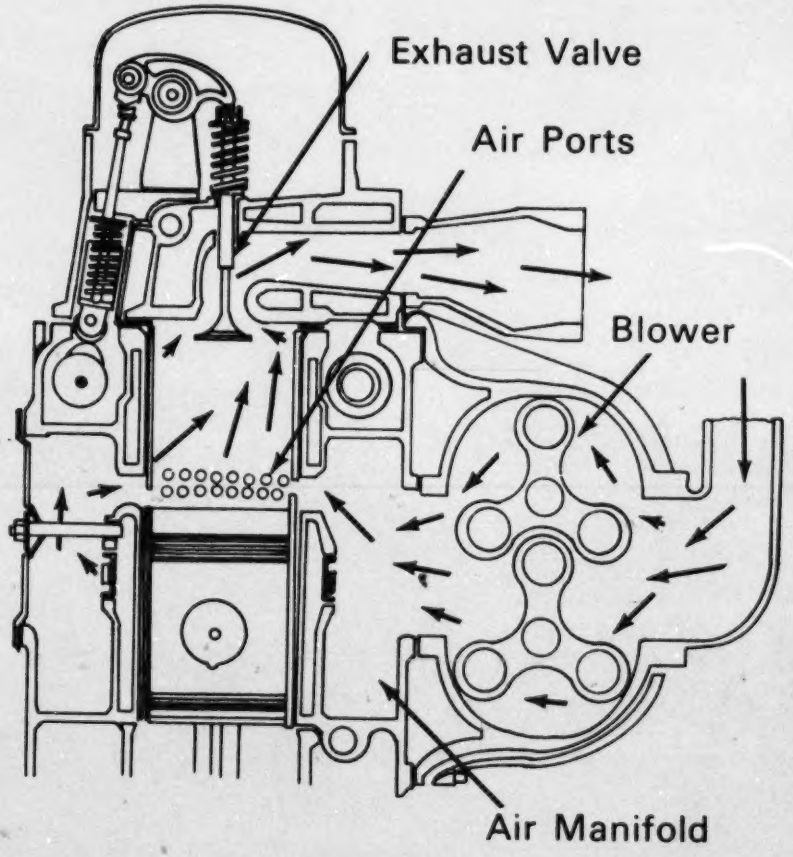
Port-Scavenged Engine



Valve-Scavenged Engine



V-TYPE

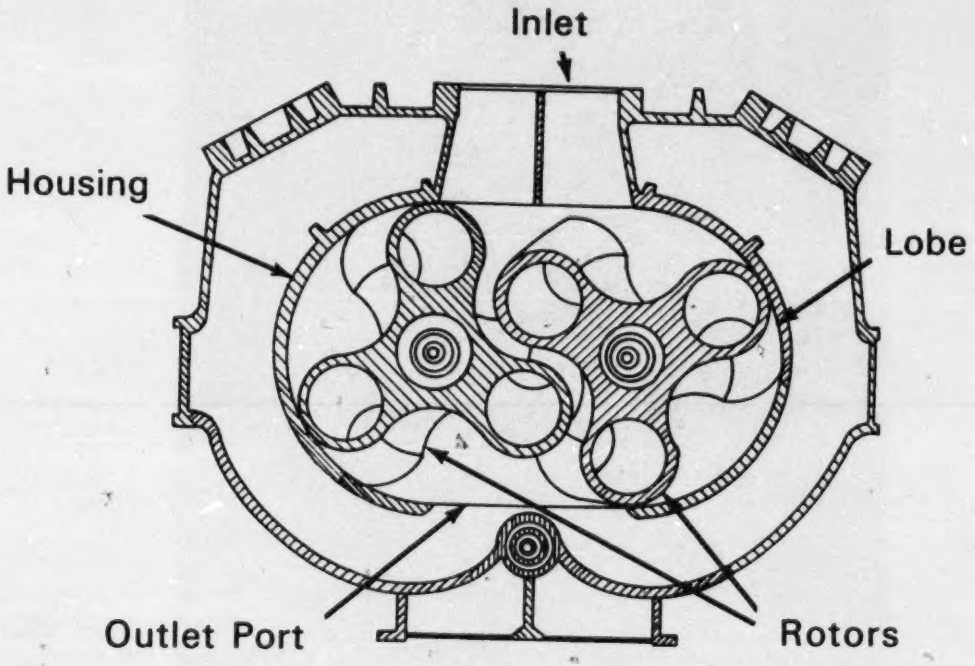


IN-LINE-TYPE

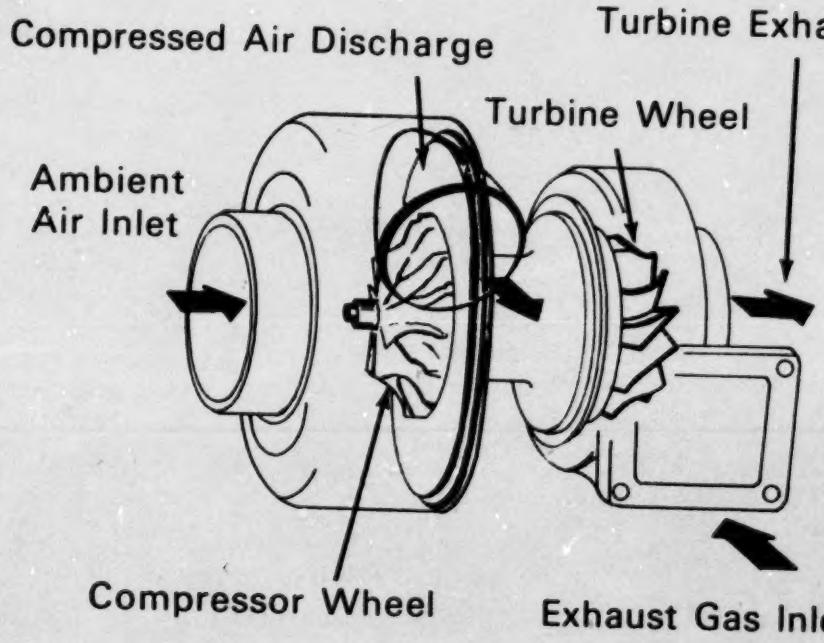
TM 7

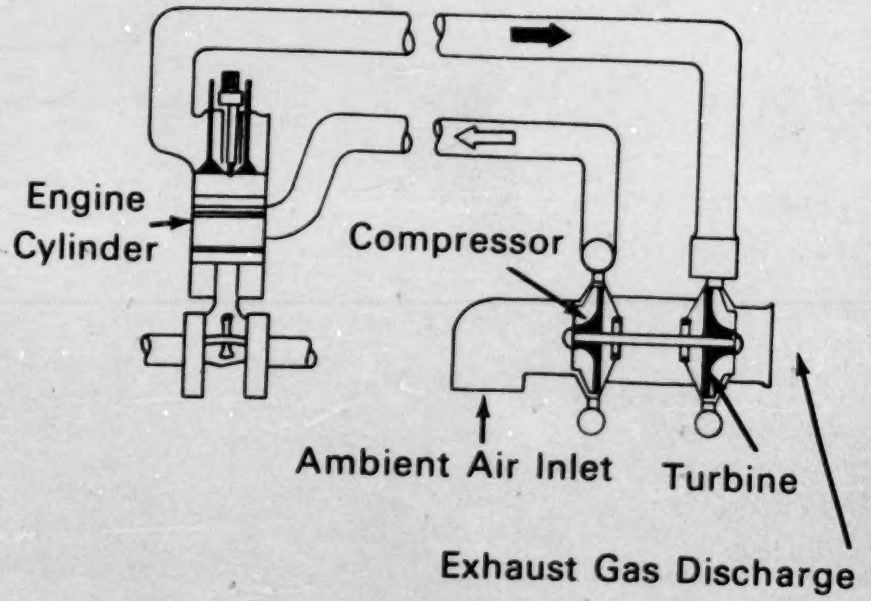
D - 99-D

Positive Displacement Supercharger



Centrifugal Type Supercharger





Engine Exhaust Gas Flow

Compressed Air Flow

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III

JOB SHEET #1--TEST AN ENGINE FOR AIR FLOW RESTRICTION

I. Tools and materials

A. Vacuum gauge

B. Basic hand tool set

C. Live engine

D. Shop towels

E. Engine technical manual

F. Safety glasses

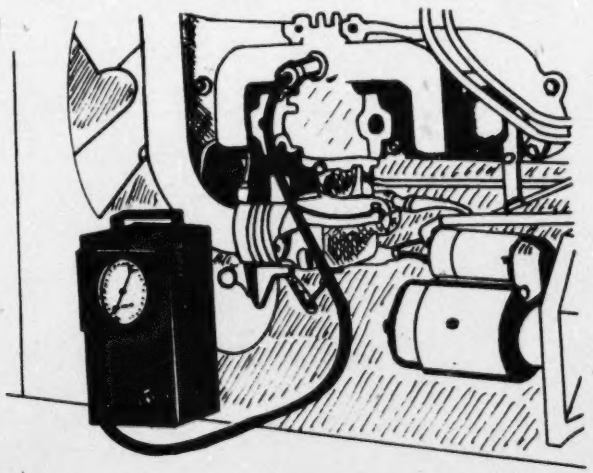
II. Procedure

(NOTE: When the air flow is restricted there is more vacuum or suction in the cylinders. This can cause oil to be drawn in around the valve stems and pistons and so increase oil consumption.)

A. Warm up the engine

B. Connect the vacuum gauge to the intake manifold (Figure 1)

FIGURE 1



C. Set engine speed at fast idle

D. Compare the reading on the gauge to the specifications in the engine technical manual

(NOTE: Too high a reading means that there is a restriction in the air intake system.)

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III

JOB SHEET #2--INSPECT A TURBOCHARGER FOR SATISFACTORY OPERATION

I. Tools and materials

A. Basic hand tool set

B. Live engine with turbocharger

C. Shop towels

D. Safety glasses

II. Procedure

A. Inspect the mounting and connections of the turbocharger to be certain they are secure and there is no leakage of oil or air

B. Check the engine crankcase to be sure there is no restriction to oil flow

C. Operate the engine at approximate rated output and listen for unusual turbocharger noise

(CAUTION: If a shrill whine (other than normal) is heard, stop the engine immediately. The whine means that the bearings are about to fail. Remove the turbocharger for inspection.)

(NOTE: Do not confuse the whine heard during "run down", as the engine stops, with a bearing failure during operation. Other unusual turbocharger noises could mean improper clearance between the turbine wheel and housing. If such noises are heard, remove the turbocharger for inspection. See the engine technical manual.)

D. Check the turbocharger for unusual vibration while engine is operating at rated output

(NOTE: Unusual vibrations like noise may require that the turbocharger be removed and inspected.)

E. Check engine under load conditions

(NOTE: Excessive exhaust smoke indicates incorrect fuel-air mixture. This could be due to engine overload or turbocharger malfunction.)

F. Inspect and service air cleaner according to instructions in the operator's manual

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III

JOB SHEET #3--REMOVE, DISASSEMBLE, SERVICE, ASSEMBLE, AND INSTALL A TURBOCHARGER

I. Tools and materials

A. Engine with turbocharger

B. Basic hand tool set

C. Chain hoist

D. Lifting sling

E. Torque wrench

F. Dial indicator

G. Soft hammer

H. Compressed air source

I. Noncaustic solvent

J. Silicone carbide abrasive cloth

K. Crocus abrasive cloth

L. Eye protection

M. Shop towels

N. Appropriate service manual

II. Procedure

A. Remove turbocharger

1. Disconnect the exhaust manifold adaptor attached to the turbine housing

2. Disconnect the air inlet hose attached to the compressor housing

3. Remove the oil inlet line from the top of the center housing

4. Remove the oil outlet line from the bottom of the center housing

JOB SHEET #3

5. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly

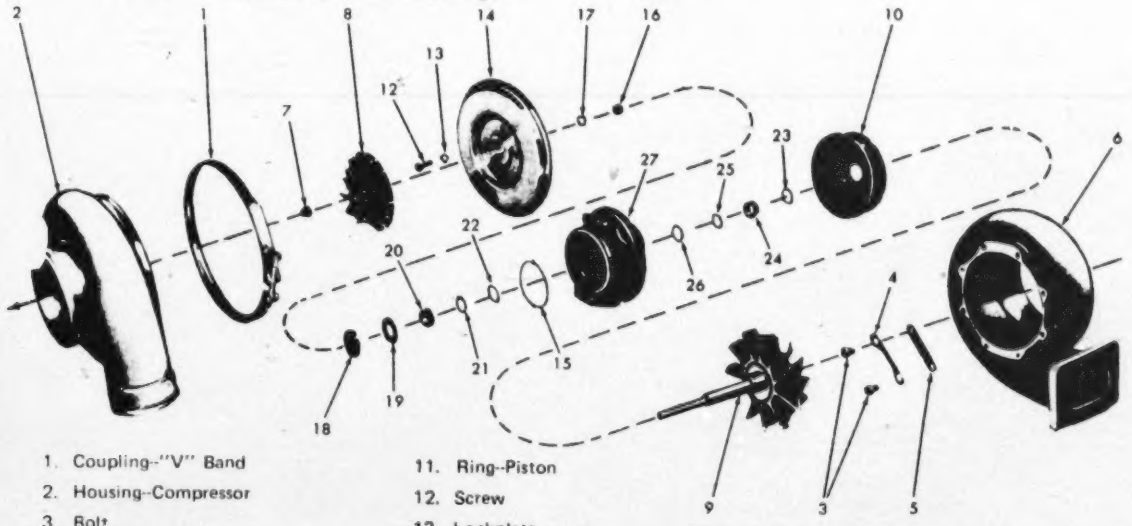
6. Remove the nuts and lock washers securing the turbocharger assembly to the mounting bracket

7. Lift the turbocharger assembly away from the engine and place it on a bench

8. Cover the end of each oil inlet and oil outlet line and the air inlet and exhaust outlet openings on the engine to prevent the entry of foreign material

9. Clean the exterior of the turbocharger with noncaustic cleaning solvent before disassembly

B. Disassemble turbocharger



1. Coupling--"V" Band
2. Housing--Compressor
3. Bolt
4. Lockplate
5. Clamp--Turbine Housing
6. Housing--Turbine
7. Nut--Self-Locking
8. Wheel--Compressor
9. Shaft--Turbine Wheel Assembly
10. Shroud--Turbine Wheel
11. Ring--Piston
12. Screw
13. Lockplate
14. Backplate Assembly
15. Ring--Seal
16. Spacer--Thrust
17. Ring--Piston
18. Collar--Thrust
19. Washer--Inboard Thrust
20. Bearing
21. Washer--Bearing
22. Ring--Snap
23. Ring--Snap
24. Bearing
25. Washer--Bearing
26. Ring--Snap
27. Housing--Center

FIGURE 1

1. Loosen the "V" band coupling securing the compressor housing (2) to the backplate assembly (14)

2. Remove the compressor housing and "V" band (Figure 1)

3. Remove the eight bolts (3) securing the four lockplates (4) and turbine housing clamps (5) to the center housing (27) and turbine housing (6).

JOB SHEET #3

4. Remove the turbine housing from the center housing

(CAUTION: Exercise care when removing the center housing and turbine housing to prevent damage to the compressor of the turbine wheel.)

(NOTE: Tap the housing with a soft hammer if force is needed for removal.)

5. Position the turbine wheel (9) of the center housing assembly in a suitable holding fixture

6. Remove the wheel nut (7) from the shaft

(CAUTION: To prevent the possibility of bending the turbine wheel shaft, remove the compressor wheel nut from the shaft with a double universal socket and tee handle.)

7. Press the compressor wheel (8) from the wheel shaft assembly (9)

8. Withdraw the wheel shaft assembly (9) and the wheel shroud (10) from the center housing

9. Remove the four bolts (12) and lockplates (13) securing the backplate assembly (14) to the center housing (27)

10. Remove the backplate assembly

11. Remove the seal ring (15) from the groove in the center housing

12. Remove the thrust spacers (16) and piston ring (17) from the backplate assembly

13. Remove the thrust collar (18), inboard thrust washer (19), bearing (20), bearing washer (21), and snap ring (22) from the center housing

14. Remove the snap ring (23), bearing (24), bearing washer (25), and snap ring (26) from the opposite end of the center housing

C. Clean turbocharger

(NOTE: Before cleaning, inspect the parts for signs of burning, rubbing, or other damage which might not be evident after cleaning.)

1. Soak all parts in a noncaustic cleaning solvent for about 25 minutes.

2. After soaking, use a stiff bristle brush and remove all dirt particles

JOB SHEET #3

3. Dry all of the parts thoroughly

(CAUTION: Never use a caustic cleaning solution for cleaning as this will damage certain parts. Use the cleaning solution in an open or well ventilated area. Avoid breathing the fumes. Keep away from open flames. Do not use a wire brush or a steel blade scraper to clean the parts.)

(NOTE: Make sure that both wheel blades are thoroughly clean. Deposits left on the blades will affect the balance of the rotating assembly.)

4. Clean all of the internal cavities and oil passages in the center housing thoroughly with dry compressed air

5. Clean the oil passage in the center housing thrust plate with dry compressed air

6. Remove the oil inlet and outlet lines from the engine and thoroughly clean the oil lines inside and out

(NOTE: An oil line that is dented or crimped enough to restrict the flow of oil must be replaced.)

D. Inspect turbocharger

1. Inspect all of the parts for signs of damage, corrosion, or deterioration

2. Check for nicked, crossed, or stripped threads

3. Visually check the turbine wheel for signs of rubbing

4. Inspect the shaft for signs of scoring, scratches, or bearing seizure

5. Check the compressor wheel for signs of rubbing or damage from foreign material

6. Check to see that the wheel bore is not galled

(NOTE: The wheel must be free of dirt and other foreign material.)

7. Inspect the seal parts for signs of rubbing or scoring of the running faces

8. Inspect the housing for contact with the rotating parts

(NOTE: The oil and air passages must be clean and free of obstructions.)

JOB SHEET #3

9. Using a silicone carbide abrasive cloth for aluminum parts, or a crocus abrasive cloth for steel parts, burnish or polish any minor surface damage that may appear

10. Replace the bearings and thrust washer if they show signs of nicks, scores, shellac deposits, or foreign material imbedment

    (NOTE: It is recommended that when one rotor shaft bearing needs replacement that both bearings be replaced at the same time.)

11. Inspect the exhaust outlet elbow seal ring for signs of wear or breakage

E. Assemble turbocharger

(NOTE: Check each part prior to installation to ensure cleanliness. As the parts are assembled, cover the openings to prevent entry of dirt or other foreign material.)

1. Lubricate the bearings (20 and 24) with clean engine oil

2. Install a new snap ring (26), bearing washer (25), bearing (24), and new snap ring (23) in the turbine end of the center housing (27)

3. Install a new snap ring (22), bearing washer (21), and bearing in the compressor end of the center housing

4. Install a new piston ring (17) on the thrust spacer (16) and gently insert the spacer into the backplate assembly (14)

   (NOTE: Do not force the piston ring into place.)

5. Position the inboard thrust washer (19) against the center housing with the hole and cutout in the thrust washer in alignment with the pins in the center housing

6. Install the thrust collar snugly against the thrust washer

7. Lubricate the thrust collar and thrust washer with clean engine oil

8. Install a new seal ring (15) in the groove at the compressor end of the center housing

JOB SHEET #3

9. Align the oil feed holes in the center housing (27) and the backplate assembly (14) and attach the backplate to the center housing with four bolts (12) and new lockplates (13)

10. Tighten the bolts to manufacturer's specified torque and bend the lockplate tangs up against the side of the bolt heads

    (NOTE: If a new backplate with a warning plate is inadvertently installed, the warning plate must be removed and the three drive screw holes plugged to prevent air leakage.)

11. Position the wheel shroud (10) against the center housing (27) and insert the wheel shaft assembly (9) through the wheel shroud and into the center housing

    (NOTE: Be careful not to scuff or scratch the bearings when installing the shaft.)

12. Place the turbine wheel shaft assembly, shroud, center housing, and backplate upright in a suitable holding fixture

13. Heat the compressor wheel in an oven, furnace, or hot oil bath to 325°F-375°F for no more than 10 minutes

14. Position the compressor wheel over the shaft and install the wheel retaining nut

15. Tighten the nut to manufacturer's specified torque while the compressor wheel is still hot

16. After the compressor wheel has cooled to room temperature, loosen the retaining nut and inspect the nut face and the front face of the compressor wheel to be sure they are smooth and clean

17. Apply a small amount of clean engine oil to the nut threads and the nut and wheel contact faces

18. Tighten the retaining nut to manufacturer's specified torque

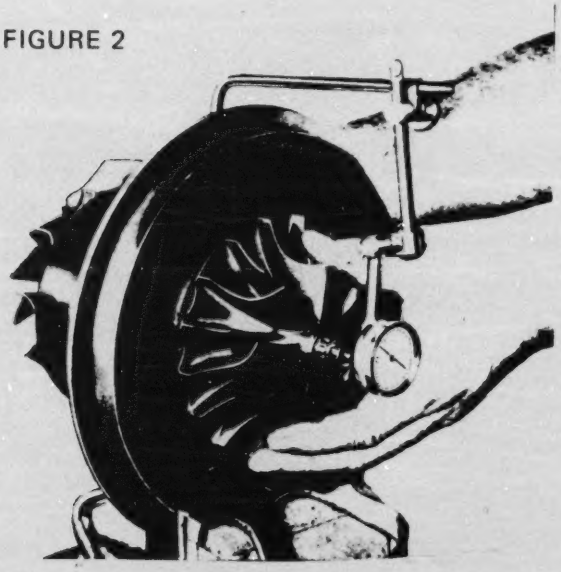
    (NOTE: Tighten the retaining nut in such a manner so as not to impose a bending load on the shaft.)

JOB SHEET #3

19. Check the bearing axial end play

a. Clamp the center housing assembly in a bench vise equipped with soft jaws (Figure 2)

FIGURE 2



b. Fasten a dial indicator with magnetic base to the center housing so that the indicator tip rests on the end of the rotating shaft on the compressor side (Figure 2)

c. Move the shaft axially back and forth by hand

(NOTE: If the total dial indicator readings do not fall within the manufacturer's specified limits, repair or replace the rotating assembly.)

20. Position the turbine housing (6) against the center housing (27) and secure it in place with four clamps (5), four new lockplates (4), and eight bolts (3).

21. Tighten the bolts to 100-110 lb-in torque

22. Position the compressor housing (2) against the center housing (27) and secure it in place with the "V" band coupling (1)

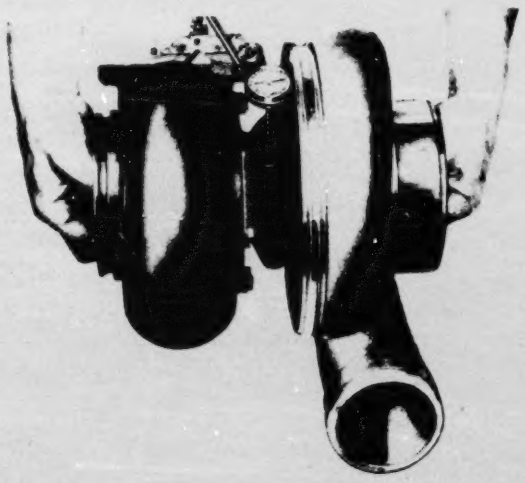
23. Tighten the nut on the "V" band coupling to manufacturer's specified torque

JOB SHEET #3

24. Check the shaft radial movement

a. Position the magnetic base with the swivel adaptor on the flat surface of the turbine housing inlet flange (Figure 3)

FIGURE 3



b. Fasten the dial indicator extension rod to the dial indicator and attach the dial indicator to to the swivel adaptor

c. Insert the extension rod into the oil drain tube mounting pad opening so that the rod is against the wheel shaft and is perpendicular to the shaft

(NOTE: Make sure the extension rod does not make contact with the sides of the center housing, otherwise it will be impossible to obtain an accurate reading.)

d. Grasp each end of the rotating assembly and, applying equal pressure at each end, move the rotating shaft first toward and then away from the dial indicator, creating a transverse movement in the shaft (Figure 3)

(NOTE: If the displacement does not fall within these limits, disassemble and repair or replace the rotating assembly.)

JOB SHEET #3

25. Stamp the letter "R" in the lower left hand corner of the nameplate to identify that the turbocharger has been reworked

F. Install turbocharger

1. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly

2. Remove the covers from the air inlet and exhaust outlet openings on the engine that were placed over the openings when the turbocharger was removed

3. Place the turbocharger assembly into position on the mounting bracket

4. Secure the turbocharger to the mounting bracket with bolts, lock washers, and nuts

   (NOTE: Tighten the nuts just enough to hold the turbocharger tight against the bracket.)

5. Slide the blower air inlet tube hose over the compressor housing outlet opening and secure it in place with the hose clamps

6. Tighten the turbocharger to exhaust manifold adaptor bolts securely

7. Remove the chain hoist and lifting sling from the turbocharger

8. Install the oil drain line between the opening in the bottom side of the center housing and the cylinder block

9. Attach the oil inlet line to the cylinder block

10. Before starting the engine, make sure that there is adequate lubricating oil in the turbocharger

    a. Clean the area around the oil inlet opening, then pour about four ounces of engine oil in the oil inlet opening of the center housing

    b. Turn the rotating assembly by hand to coat the bearings, thrust washers and thrust collar with oil

    c. Hold the compressor wheel from turning and start the engine and run it at idle speed

JOB SHEET #3

d. As soon as oil appears at the end of the oil supply line, connect the oil inlet line to the top of the center housing

(NOTE: Compare oil pressure to manufacturer's specification.)

e. After the oil inlet line is attached, release the compressor wheel

11. Check all ducts and gaskets for leaks

12. Operate the engine at idle speed for a short period to provide adequate lubrication to the turbocharger bearings

13. Run at rated output and listen for sounds of metallic contact from the turbocharger

(NOTE: If any such noise is apparent, shut down the engine immediately and correct the cause. After the turbocharger has been operating long enough to permit the unit and the oil to warm up, the rotating assembly should coast freely to a stop after the engine is stopped. If the rotating assembly jerks to a sudden stop, the cause should be immediately determined and eliminated.)

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III

JOB SHEET #4 DISASSEMBLE, SERVICE, REPAIR, AND ASSEMBLE A SUPERCHARGER

I. Tools and materials

A. Basic hand tool set

B. Arbor press

C. Vise with protective jaws

D. Feeler gauge

E. Soft hammer

F. Lock wire

G. Compressed air source

H. Noncaustic solvent

I. Mineral spirits

J. Shop towel

K. Eye protection

L. Appropriate service manual

II. Procedure

A. Disassemble supercharger

(NOTE: Visually inspect rotors and case surfaces through inlet and outlet ports before dissassembling supercharger. If severe scoring, roughness, or cracks are found, replace entire assembley with a rebuilt unit.)

1. Remove intake and discharge connections

2. Cover both openings and wash exterior of supercharger with mineral spirits

(CAUTION: Do not use any solution that will damage finished surfaces or aluminum.)

3. Mount supercharger in vise, clamping supercharger at intake housing only tight enough to stabilize it

(NOTE: Make sure jaws are covered with copper or other protective materials.)

JOB SHEET #4

4. Remove pipe bushing from end plate cover; remove oiler spring and plunger

5. Pry up on collar on recessed washer at rear or drive rotor shaft; remove locknut and washer

   (NOTE: Some models require special spanner wrench.)

6. Remove generator drive coupling, if used

   (NOTE: Some models require special puller.)

7. Remove capscrews from end plate cover

8. Carefully pry cover from dowels using a small screwdriver at each end of cover

9. Drive out oil seal

10. Pry ears of recessed washer up and out of slots in locknut on rotor shafts at plain end of supercharger and on drive coupling locknut at gear end of supercharger

11. Lock rotors with coupling locking wrench; remove locknut at plain end and locknut in drive coupling

12. Remove drive coupling from shaft using puller

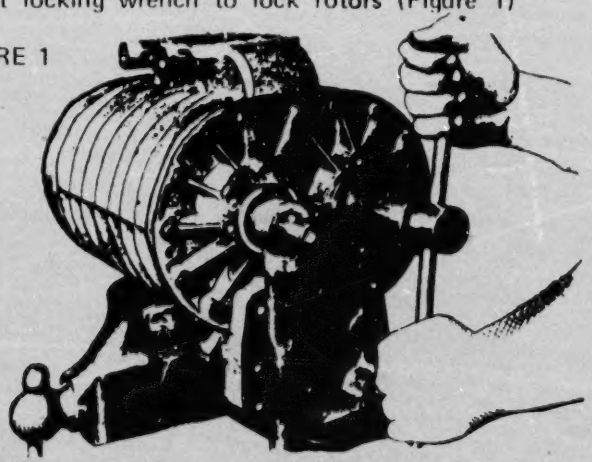
13. Remove drain plug from bottom of gear cover and drain oil

14. Remove capscrews from gear end plate cover and remove cover

15. Remove oiler retainer, spring key washer, and plug from gear cover

16. Remove locknut and lockwasher **from idler** rotor shaft end using shaft locking wrench to lock rotors (Figure 1)

FIGURE 1



JOB SHEET #4

17. Remove socket head capscrews from gear end plate

18. Remove end plate rotor and gears as a unit from housing.

19. Carefully tap plate at each end with rubber hammer to remove from housing dowels

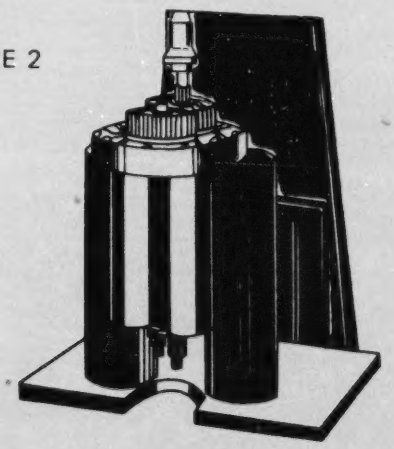
20. Check each rotor for the proper timing marks and position

(NOTE: One rotor will have an X mark along the gear end of the air line. The other rotor will have an X mark in the gear end of the valley. When properly assembled, these two X marks will pass together each time the supercharger rotates. If the rotors do not have timing marks, it will be necessary to mark the rotors prior to removal from end plate. When reassembling the unit, the rotors must operate in the same position as they did before disassembly. Keep all rotors in matched pairs when rebuilding more than one unit.)

21. Support under side of end plate near rotors and press out each rotor shaft

22. Mark each gear so it can be replaced on shaft which it was removed (Figure 2)

FIGURE 2



23. Remove rotors from housings

(NOTE: When rotors are removed from housings, inner races of roller bearings usually remain on shafts. Remove them carefully, avoiding damage to shafts.)

JOB SHEET #4

24. Remove screws from each bearing retainer plate on gear end plate; remove retainers

25. Press bearings out of gear end plate

26. Remove capscrews from plain end plate

27. Remove end plate from housing dowels by carefully tapping plate at each end with a rubber hammer

28. Drive bearing outer races and rollers out of end plate

29. Remove piston ring seals from both ends of rotor shafts

B. Clean and inspect supercharger

1. Discard all gaskets, oil seals, recessed washers, roller bearings and ball bearings

2. Clean all parts with approved cleaning solvent and dry thoroughly

3. Inspect rotors, housing and end plates for cracks, abrasions, wear spots and build-up of foreign material and smooth all worn or rough spots with fine emery cloth

4. Wash clean in approved solvent and dry

5. Discard cracked, broken or damaged parts

(NOTE: Rotors and shafts are not separable and must be replaced as a matched rotor set or unit.)

6. Inspect drive coupling for worn pins, distorted or displaced rubber bushings and damaged or worn internal splines

7. Examine hub surface under oil seal and replace coupling if surface is grooved or seriously worn

8. Check gear fit on rotor shafts, matching gears to shafts from which removed

9. Check gear teeth for evidence of chatter and wear

10. Replace rotors and gears if gears are not a good press-fit on shafts

11. Mount gears on four-inch centers and check backlash between gears

(NOTE: Compare reading with manufacturer's specifications.)

JOB SHEET #4

12. Mount drive rotor on V-blocks at bearing journals

13. Set up dial indicator to bear on outside diameter of splines at shaft ends

(NOTE: Check manufacturer's specifications for run out readings.)

14. Inspect all dowels, oiler plungers, piston ring seals and gasket surfaces and replace as necessary

C. Repair and assemble supercharger

1. Press new double-row ball bearings into gear end plate

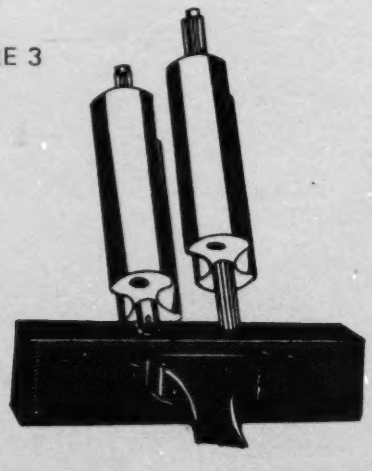
2. Position bearing retainers and secure with screws and lockwashers

3. Install piston seal rings on rotor shafts

4. Construct on assembly block (Figure 3)

(NOTE: Drill holes slightly larger than shaft diameter.)

FIGURE 3



5. Position rotors on block with plain end of shafts in holes, gear end up

(CAUTION: Do not damage shaft seal rings.)

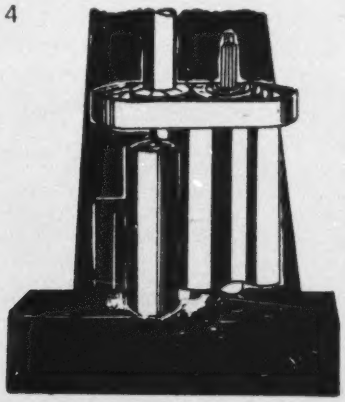
6. Move block of wood with rotors in place to arbor press and install gear end plate so rotor shafts enter proper bearings

JOB SHEET #4

7. Press bearings over shafts with appropriate mandrel and sleeve

(CAUTION: Make certain seal rings on rotor shafts enter end plate without damage. See Figure 4.)

FIGURE 4

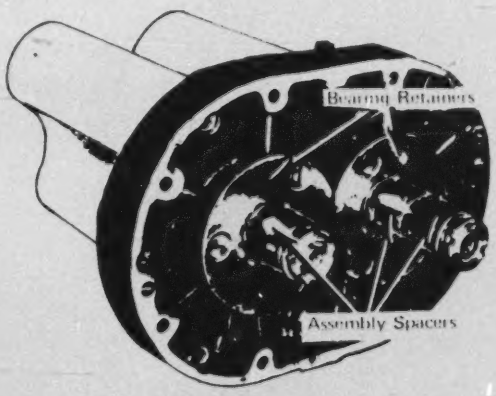


8. Install temporary spacers on shaft ends

9. Install and tighten two shaft locking nuts

(NOTE: Some superchargers require a special shaft locking wrench. See Figure 5)

FIGURE 5

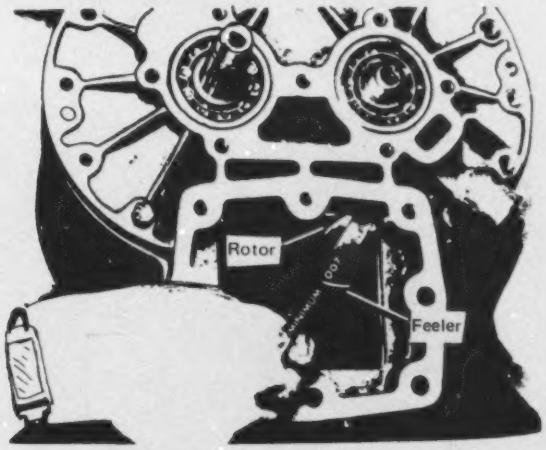


JOB SHEET #4

10. Check end clearance with feeler gauge (Figure 6)

(NOTE: If manufacturer's specified clearance is not obtained, remove locking nuts and temporary spacers; press rotor shafts from bearings.)

FIGURE 6



11. Add or remove shims between shaft shoulder and bearing inner race to obtain manufacturer's specified clearance

12. Reassemble parts and recheck clearance

13. Repeat above procedure, if necessary, until proper clearance is obtained

14. Remove two locking nuts and temporary spacers from rotor shafts

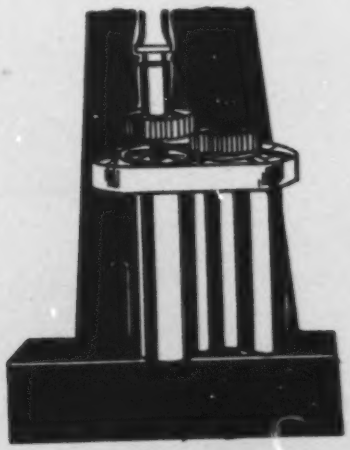
15. Press same gear on drive shaft that was removed, unless new gears are used

JOB SHEET #4

16. Position rotors at right angles to each other with the timing marks in the proper position and press other gear on idler rotor shaft (Figure 7)

(NOTE: The rotor timing marks will only ensure the proper valley to lobe relationship. When installing gears, the rotors must be at a 90° angle to each other. Disregard timing marks on gears.)

FIGURE 7



17. Remove rotor and end plate assembly from arbor press

18. Separate inner races or new roller bearings and drive races on plain ends of rotor shafts

19. Assemble rotor, end plate and gear assembly to housing, using new gasket

20. Install socket head capscrews with new copper washers

21. Tighten evenly and securely, using lockwire to secure

22. Position plain end plate on housing

(NOTE: Engage dowels in proper holes evenly, assemble capscrews and lockwashers and tighten on alternate sides evenly.)

23. Install new roller bearing outer races and rollers over inner races into plain end plate bore

(NOTE: Make certain bearing name is toward outside.)

JOB SHEET #4

24. Check clearances between rotors and rotor housing, rotors and plain end plate, and between rotors

(NOTE: Use long feeler gauge from tool kit through inlet and outlet ports of housing. See Figures 8 and 9.)

FIGURE 8

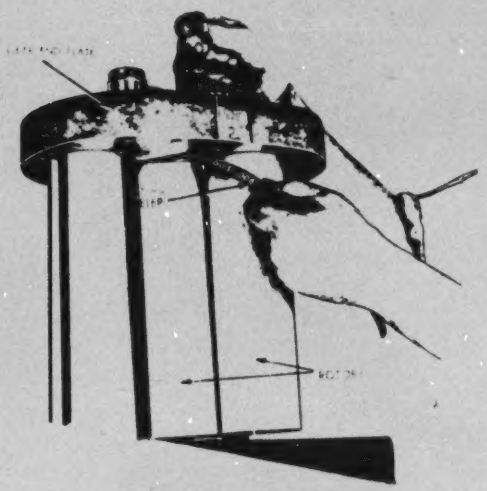
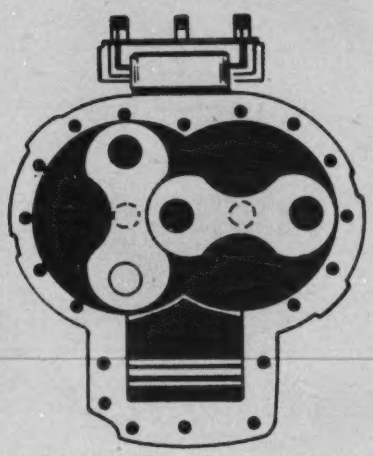


FIGURE 9



25. Check clearance between rotors

(NOTE: If clearances cannot be obtained, disassemble and thoroughly check all parts. Additional shims can be installed between gear end plate and housing to obtain proper clearance at opposite ends of rotors and plain end plate. If other clearances cannot be obtained, replace supercharger.)

JOB SHEET #4

26. Position new recessed washers on each end of driven motor shaft and install two nuts

(NOTE: Hold drive shaft by placing a clean block of wood between rotors. Tang on inner part of washer must fit into keyway of shaft. Tighten nuts with special spanner and stake side of washer into slot of nut after tightening.)

27. Assemble new gasket to plain end plate and install end plate cover

28. Install lockwashers and capscrews and tighten evenly

29. Install one new oil seal in cover bore

(NOTE: Sealing lips should be in; toward rotors and flush with housing.)

30. Press generator drive coupling on shaft

(NOTE: While pressing on coupling, always rest unit on opposite end of shaft.)

31. Install generator coupling lockwasher and locknut

32. Tighten securely and lock

33. Replace oiler plunger and spring in gear cover

(NOTE: Make sure small oil hole is clean and slots in plunger line up with spring retainer fitting or cover will not pull up to end plate.)

34. Install new oil seal flush with gear cover with sealing lips in

35. Assemble cover with a new gasket to gear end plate and install lockwashers and capscrews

36. Tighten on alternate sides securely

37. Assemble oiler plunger, spring and fitting into plain end bearing cover

(NOTE: Radius on end of pin must fit radius of spacer. Oil hole must be clean and pin must work freely.)

38. Replace oil drain hose fitting in gear end cover

JOB SHEET #4

39. Support entire assembly on drive rotor shaft at plain end and press drive coupling onto splines at drive end

    (NOTE: Press on coupling flange, not pins.)

40. Install recessed washer and nut to drive rotor shaft threads

41. Tighten securely with special spanner

42. Hold shaft from turning with coupling locking wrench

43. Lock washer into nut slots after tightening

44. After supercharger is installed to engine, add one quart of engine lubricating oil to gear end plate through pipe plug hole

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III

NAME _____

TEST

1. Match the terms on the right to the correct definitions.

_____a.	Unit containing an element of varying degrees of fineness to trap foreign particles	1.	Scavenging
_____b.	Method of pushing air out of the cylinders during the exhaust stroke on two-cycle engines	2.	Filter
_____c.	Opening in a cyclinder block or liner for intake and/or exhaust air on two-cycle engines	3.	Blower
_____d.	Device for sealing the intake and/or exhaust ports in a cylinder head	4.	Supercharging
_____e.	Method of increasing air pressure and velocity	5.	Turbocharger
_____f.	Positive displacement blower to raise intake air above atmospheric pressure	6.	Naturally aspirated
_____g.	Exhaust-driven turbine which drives a centrifugal compressor	7.	Port
_____h.	Pipe or casting with multiple openings to connect multiple cylinders to one outlet or inlet	8.	Valve
_____i.	Method of charging cylinders with fresh air above atmospheric pressure on the intake stroke	9.	Roots type blower
_____j.	Engine which is not supercharged	10.	Manifold
_____k.	Device to collect some dirt from air before it enters the main air cleaner	11.	Precleaner

2. Name four parts of an air intake system.

a.

b.

c.

d.

3. Name four parts of an exhaust system.

   a.

   b.

   c.

   d.

4. Discuss three types of air cleaners.

5. Discuss three methods of scavenging the cylinders on a two-stroke cycle engine.

6. Distinghish between port scavenging and valve scavenging in two-cycle engines by placing an "X" next to the description of port scavenging.

_____a. Air enters through ports in the cylinder block and gases leave through valves in the cylinder head

_____b. Air enters and gas leaves through ports in the cylinder block or liner which the piston uncovers

7. Discuss two types of superchargers.

8. List four advantages of a turbocharged engine.

a.

b.

c.

d.

9. Demonstrate the ability to:

a. Test an engine for air flow restriction.

b. Inspect a turbocharger for satisfactory operation.

c. Remove, disassemble, service, assemble, and install a turbocharger.

d. Disassemble, service, repair, and assemble a supercharger.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III

ANSWERS TO TEST

1.
a.	2	g.	5
b.	1	h.	10
c.	7	i.	4
d.	8	j.	6
e.	3	k.	11
f.	9		

2. Any four of the following:
   a. Precleaner, air cleaner
   b. Supercharger (if used)
   c. Intake manifold
   d. Piping
   e. Intake valves or ports

3. Any four of the following:
   a. Ports and/or valves
   b. Exhaust manifold
   c. Piping
   d. Muffler
   e. Turbocharger (if used)

4. Discussion should include:
   a. Dry element type--Cleaning is done by replacing element
   b. Viscous-impingement type--Cleans air by passing it through a maze of metal wool, wire, or screens saturated with oil
   c. Wet type--Cleans air by directing it through a center tube into the inner oil cup where direction of air flow is reversed causing most of the dirt to become trapped by the oil and settle in the sump

5. Discussion should include:

   a. Crankcase

      1. Air enters the engine through the crankcase

      2. Each downward movement of the piston compresses the vapor within the crankcase until the intake port or valve opens

      3. The compressed vapor escapes into the cylinder at a pressure nearly equal to atmospheric pressure

   b. Power piston

      1. Uses a separate piston and cylinder driven by the engine crankshaft

      2. Pushes the vapor into the cylinder as the intake valve or ports opens

   c. Blower

      1. Uses a positive-displacement rotary blower driven by the engine

      2. Compresses the vapor into an air chamber surrounding the intake ports

6. b

7. Discussion should include:

   a. Positive displacement

      1. Driven by a chain, belt, or gear

      2. Resembles oil pumps in design

   b. Centrifugal

      1. Driven by engine, engine exhaust, or separate motor

      2. Impeller normally moves thirty times engine speed

8. Any four of the following:

   a. Increases horsepower output of a given displacement engine

   b. Reduces weight by delivering more horsepower per pound than nonturbocharged engines

   c. Cost of a turbocharged engine is less on a dollar per horsepower basis

d. Maintains horsepower at higher altitudes

e. Reduces exhaust smoke by supplying excess air to reduce exhaust density

9. Performance skills evaluated to the satisfaction of the instructor.

STARTING SYSTEMS
UNIT IV

UNIT OBJECTIVE

After completion of this unit, the student should be able to explain the various methods used to start diesel engines and be able to identify the components necessary to operate the starting system. This knowledge will be evidenced by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with starting systems to the correct definitions.
2. Name four major types of starting systems.
3. Explain three sources of electricity that may be used in electric motor starting.
4. List two sources of compressed air for compressed air starting motors.
5. Discuss how an engine is started by compressed air admission.
6. Name components of an air admission starting system.
7. Discuss air starting systems.
8. Identify the components of a hydraulic starting system.
9. Name four components of a gasoline starting system.
10. Name three components of an electric starting system.
11. Name types of low temperature starting aids.

STARTING SYSTEMS
UNIT IV

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information sheet.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Locate an engine which uses compressed air for starting and demonstrate the starting procedures.

G. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Components of Air Admission Starting System
2. TM 2--Air Starting Systems
3. TM 3--Compressed Air Starting Motors
4. TM 4--Components of Hydraulic Starting System
5. TM 5--Starting Aids
6. TM 6--Starting Aids (Continued)

D. Test

E. Answers to test

II. References:

A. Toboldt, Bill. *Diesel: Fundamentals, Service, Repair.* South Holland, Illinois: Goodheart-Willcox Company, 1973.

B. Kates, Edgar J., and Luck, William E. *Diesel and High Compression Gas Engines.* Chicago: American Technical Society, 1974.

STARTING SYSTEMS
UNIT IV

INFORMATION SHEET

I. Terms and definitions

A. Accumulator--A device used to store hydraulic energy

B. Pinion--Gear with a small number of teeth designed to mesh with a larger gear

C. Inertia--Tendency of mass in motion to remain in motion, or if at rest to remain at rest

D. Compound--Dual, two systems

E. Plenum--Enclosed space

II. Types of starting systems

A. Hydraulic cranking motors

B. Electric motors

C. Gasoline engines

D. Compressed air cranking systems

III. Sources of electricity for electric motor starting

A. Twelve, twenty-four or thirty-two volt storage batteries driving an electric starting motor

B. Sixty-four or one hundred ten volt storage batteries driving the main generator as a starting motor

(NOTE: Diesel-electric locomotives use this system.)

C. Main switchboard in a stationary power plant where the switchboard is always energized

IV. Sources of compressed air for compressed air starting motors

A. Separate engine and compressor

B. Air brake compressor on highway diesel tractors

(NOTE: The air starting motor produces more torque to turn an engine over than an electric starter motor.)

INFORMATION SHEET

V. Starting an engine by compressed air admission

A. Air compressed in storage tanks

B. Compressed air is admitted through an automatic starting valve in engine cylinder head when the piston is at top center at start of the power stroke

C. Starting valve opening is timed by cams on the camshaft

(NOTE: Usual starting air pressures range from 250 to 350 pounds per square inch.)

VI. Components of air admission starting system (Transparency 1)

A. Pressure relief valve

B. Pressure gauges

C. Air tanks

D. Blow-off valves

E. Drain valves

F. Shut-off valves

G. Engine driven air compressor

H. Motor driven air compressor

VII. Air starting systems (Transparencies 2 and 3)

A. Air admission starting system--Compressed air admitted to engine cylinders to crank engine

B. Air motor starting system--Compressed air turns motor which engages flywheel through a bendix drive

VIII. Components of a hydraulic starting system (Transparency 4)

A. Reservoir

B. Engine driven hydraulic pump

C. Hand pump

D. Pressure gauge

E. Accumulator

INFORMATION SHEET

F. Pressure lines

G. Starter assembly

IX. Components of gasoline starting system

A. Gasoline engine

B. Clutch

C. Gear box

D. Drive pinion

X. Components of electric starting system

A. Lead acid storage batteries

B. Electric cranking motor

C. Starter switches

XI. Starting aids (Transparencies 5 and 6)

A. Special starting fluids

B. Heating coolant

C. Heating lubricating oil

D. Air heating engine

E. Heating intake air

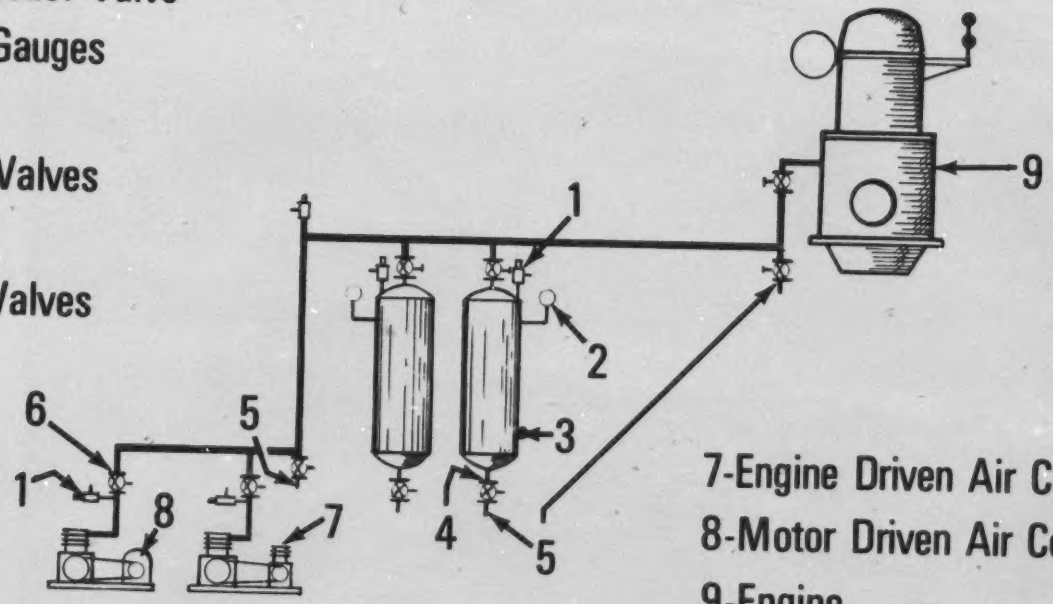
F. Glow plug

G. Heating starting battery

(NOTE: Aids may be used singly or in combination.)

Components of Air Admission Starting System

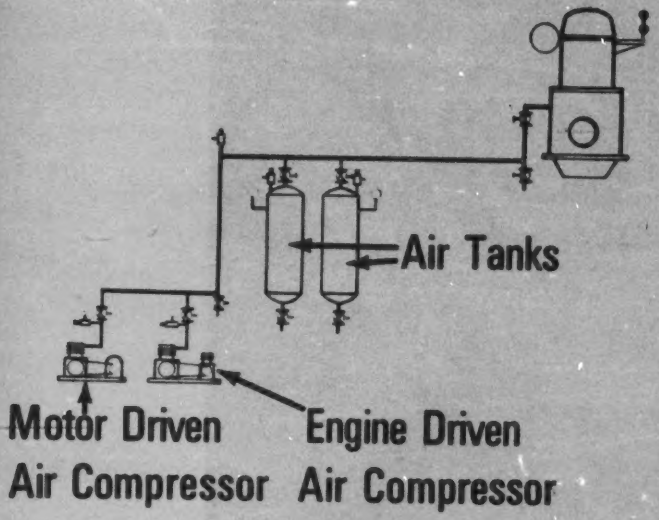
ssure Relief Valve
ssure Gauges
Tanks
w-Off Valves
n Line
t-Off Valves



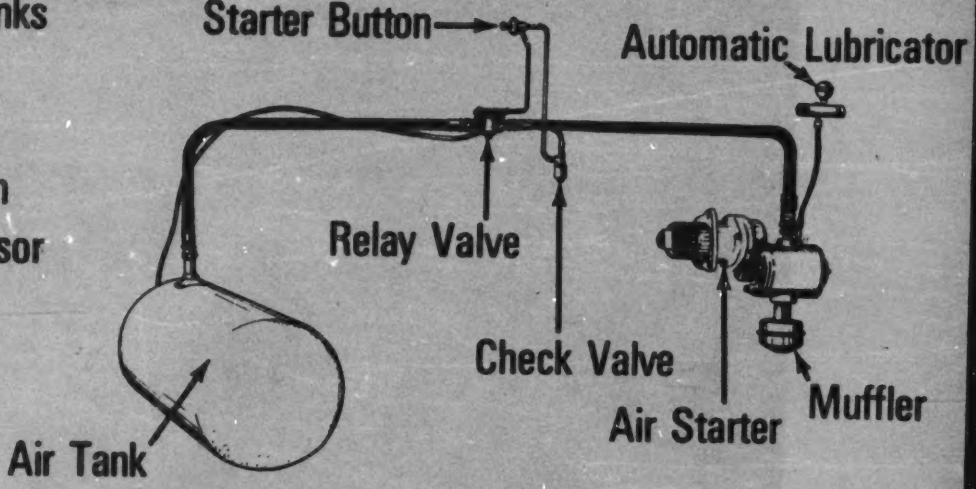
7-Engine Driven Air Compressor
8-Motor Driven Air Compressor
9-Engine

Air Starting Systems

Air Admission Starting System

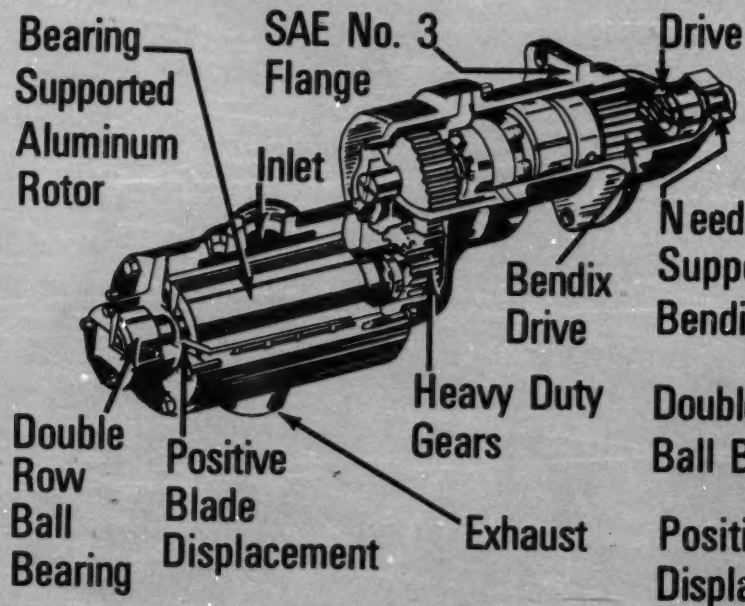


Air Motor Starting System



Compressed Air Starting Motors

Highway Tractor Air Motor and Transmission Starter System



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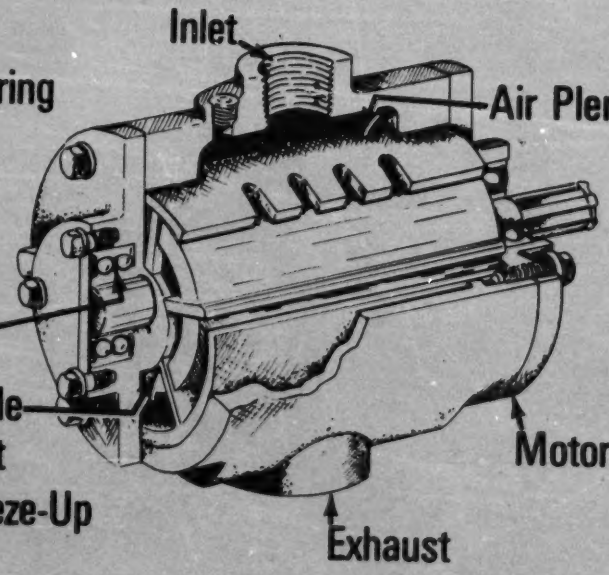
Air Starter Motor



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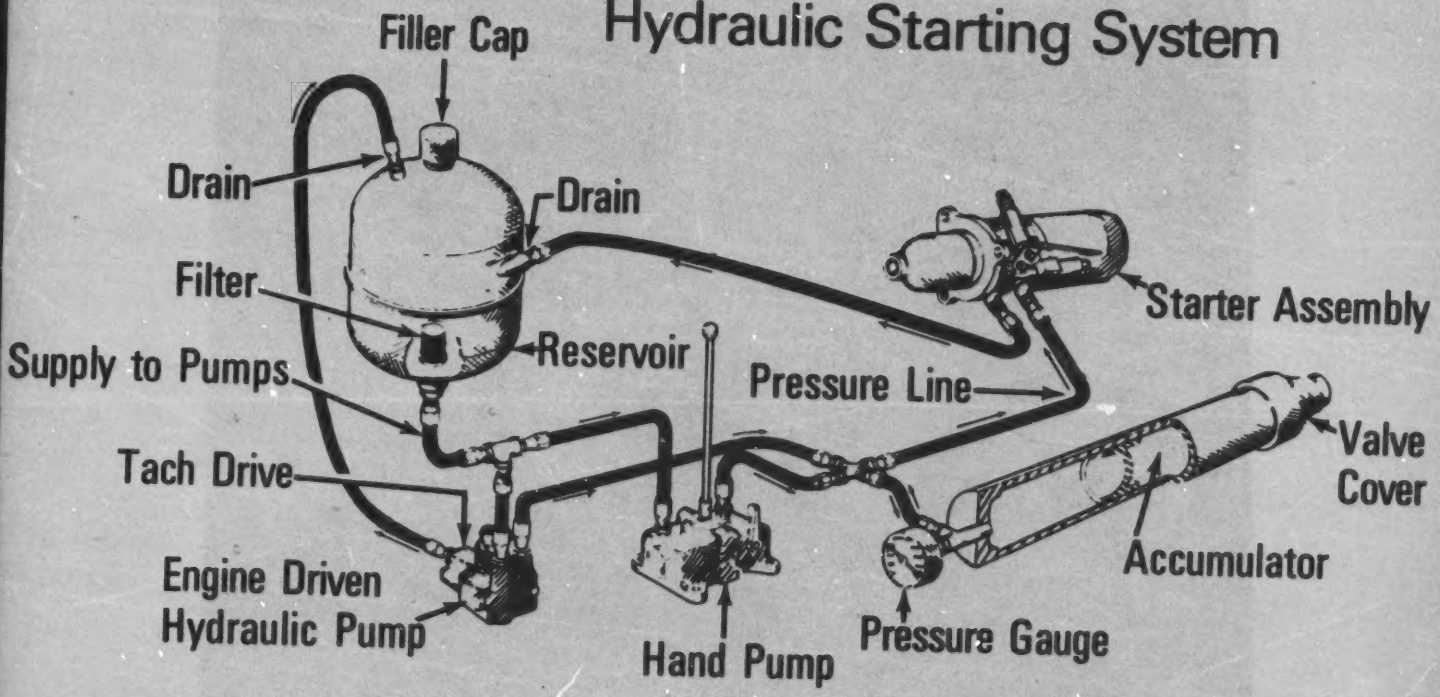
TM 3

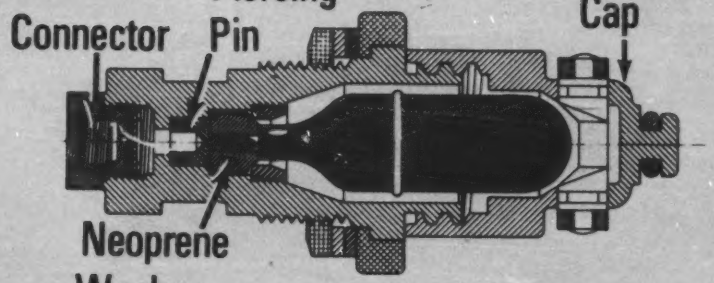
D - 151-D

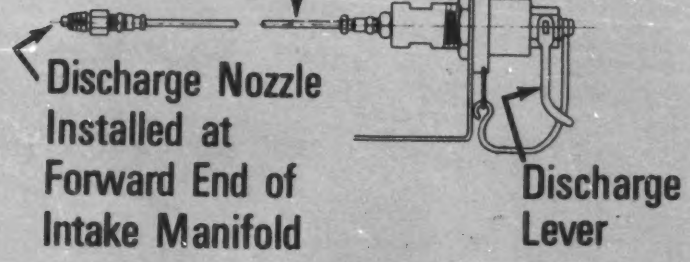
Components of Hydraulic Starting System



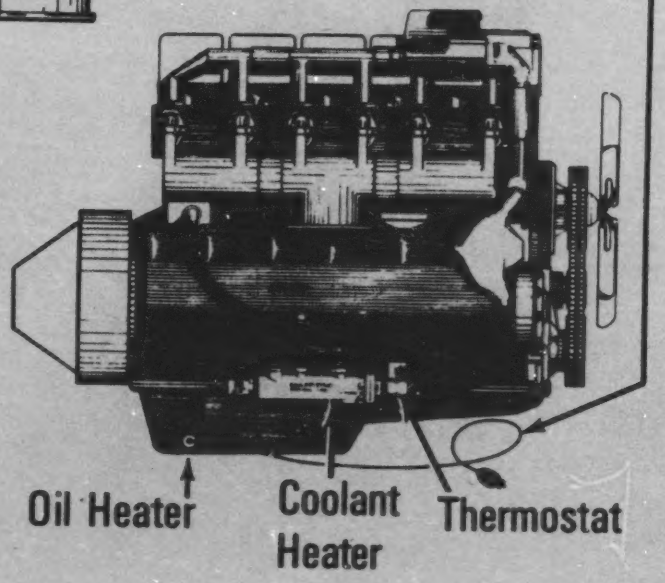
Starting Aids

Ether Capsule Primer




3/16 in. O.D. Tubing
Discharge Cell Mounted at Operator Station
Discharge Nozzle Installed at Forward End of Intake Manifold
Discharge Lever

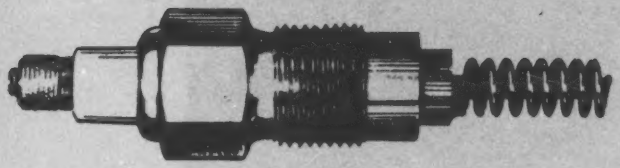
Electrically Heated

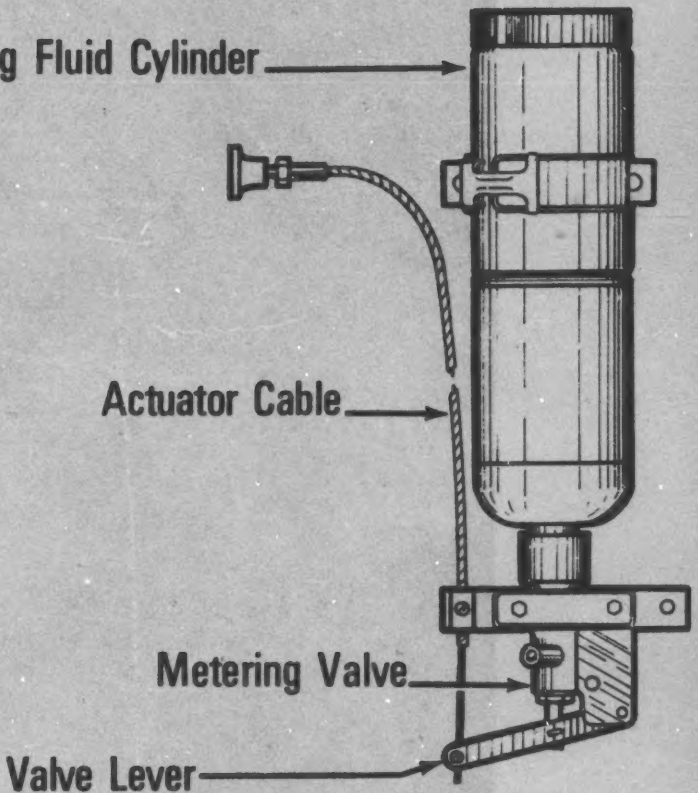


Starting Aids

(Continued)

Typical Glow Plug





STARTING SYSTEMS
UNIT IV

NAME _____

TEST

1. Match the terms on the right to the correct definitions.

_____a. A device used to store hydraulic energy	1. Inertia
_____b. Gear with a small number of teeth designed to mesh with a larger gear	2. Compound
_____c. Tendency of mass in motion to remain in motion, or if at rest to remain at rest	3. Accumulator
_____d. Dual, two systems	4. Plenum
_____e. Enclosed space	5. Pinion

2. Name four major types of starting systems.

a.

b.

c.

d.

3. Explain three sources of electricity that may be used in electric motor starting.

4. List two sources of compressed air for compressed air starting motors.

   a.

   b.

5. Discuss how an engine is started by compressed air admission.

6. Name five components of an air admission starting system.

   a.

   b.

   c.

   d.

   e.

7. Discuss air starting systems.

   a. Air admission starting system--

   b. Air motor starting system--

8. Identify the components of a hydraulic starting system.

a. _____

b. _____

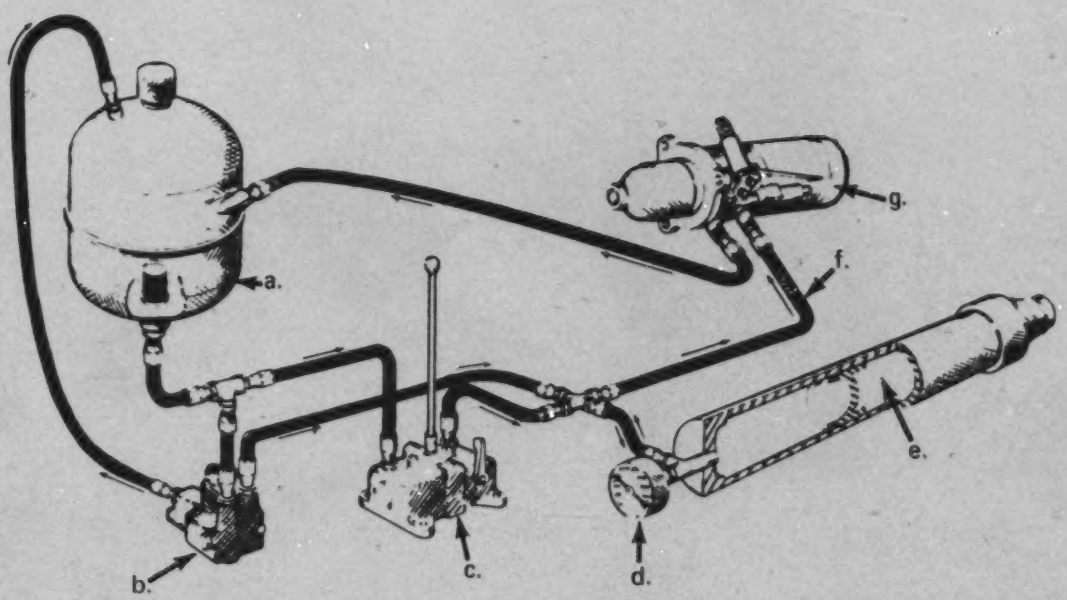
c. _____

d. _____

e. _____

f. _____

g. _____



9. Name four components of a gasoline starting system.

   a.

   b.

   c.

   d.

10. Name three components of an electric starting system.

   a.

   b.

   c.

11. Name four types of low temperature starting aids.

   a.

   b.

   c.

   d.

STARTING SYSTEMS
UNIT IV

ANSWERS TO TEST

1. a. 3
   b. 5
   c. 1
   d. 2
   e. 4

2. a. Hydraulic cranking motors
   b. Electric motors
   c. Gasoline engines
   d. Compressed air cranking systems

3. Explanation should include:
   a. Twelve, twenty-four, or thirty-two volt storage batteries driving an electric starting motor
   b. Sixty-four or one hundred ten volt storage batteries driving the main generator as a starting motor
   c. Main switchboard in a stationary power plant where the switchboard is always energized

4. a. Separate engine and compressor
   b. Air brake compressor on highway diesel tractors

5. Discussion should include:
   a. Air compressed in storage tanks
   b. Compressed air is admitted through an automatic starting valve in engine cylinder head when the piston is at top center at start of the power stroke
   c. Starting valve opening is timed by cams on the camshaft

6. Any five of the following:

   a. Pressure relief valve

   b. Pressure gauges

   c. Air tanks

   d. Blow-off valves

   e. Drain valves

   f. Shut-off valves

   g. Engine driven air compressor

   h. Motor driven air compressor

7. Discussion should include:

   a. Air admission starting system--Compressed air admitted to engine cylinders to crank engine

   b. Air motor starting system--Compressed air turns motor which engages flywheel through a bendix drive

8. a. Reservoir

   b. Engine driven hydraulic pump

   c. Hand pump

   d. Pressure gauge

   e. Accumulator

   f. Pressure lines

   g. Starter assembly

9. a. Gasoline engine

   b. Clutch

   c. Gear box

   d. Drive pinion

10. a. Lead acid storage batteries

b. Electric cranking motor

c. Starter switches

11. Any four of the following:

a. Special starting fluids

b. Heating coolant

c. Heating lubricating oil

d. Air heating engine

e. Heating intake air

f. Glow plug

g. Heating starting battery

FUEL SYSTEM COMPONENTS
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to name the major parts of a fuel system and match the parts to their functions. The student should also be able to select major functions of the fuel injection system and explain the operation of the jerk pump method of injecting fuel. This knowledge will be evidenced by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with the fuel system to the correct definitions.
2. Name five major parts of a fuel system.
3. Match the parts of the fuel system to their functions.
4. Select major functions of the fuel injection system.
5. Name three fuel tank maintenance problems.
6. Discuss air pressure testing of a fuel tank for leaks.
7. List the precautions to take before soldering or welding a fuel tank.
8. Match the types of fuel lines to their purposes.
9. Explain the purpose of the fuel transfer pump.
10. Name three types of filters used at the stages of fuel filtration on a typical diesel fuel system.
11. Distinguish between the operation of the series and parallel dual filters.
12. Name three major types of injection systems.
13. Explain the operation of the jerk pump system.
14. List four methods of injecting fuel using the pump and injection nozzle.

FUEL SYSTEM COMPONENTS
UNIT I

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information sheet.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Have students examine the difference in construction among fuel lines.

G. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Fuel System Components
2. TM 2--Types of Fuel Lines
3. TM 3--Stages of Fuel Filtration

4. TM 4--Series Dual Fuel Filters

5. TM 5-Jerk Pump and Injection Nozzle Combinations

D. Test

E. Answers to test

II. References:

A. *Fundamentals of Service: Engines.* Moline, Illinois: Deere and Company, 1972.

B. Kates, Edgar J., and Luck, William E. *Diesel and High Compression Gas Engines.* 3rd ed. Chicago: American Technical Society, 1972.

C. *Detroit Diesel Allison: Service Manual.* Detroit, Michigan: Division of General Motors Corp., 1974.

FUEL SYSTEM COMPONENTS
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Atomize--Break down into small particles

B. Fuel pump--Pressure developing unit which supplies fuel to the injector

C. Injection nozzle--Device to distribute fuel in the combustion chamber

D. Unit injector--Pump and fuel injection nozzle combined into one unit

II. Major parts of the fuel system

A. Fuel tank

B. Fuel transfer pump

C. Fuel filters

D. Fuel injection pump

E. Fuel injection nozzle

III. Functions of fuel system parts (Transparency 1)

A. Fuel tank--Stores fuel

B. Fuel transfer pump--Supplies fuel through filters to injection pump at low pressure

C. Fuel filter--Cleans the fuel

D. Fuel injection pump--Times, measures, and delivers fuel under pressure to injection nozzles

E. Fuel injection nozzle--Atomizes and sprays fuel into combustion chamber

IV. Major functions of the fuel injection system

A. Supplies the correct quantity of fuel

B. Times the fuel delivery

C. Controls the delivery rate

INFORMATION SHEET

D. Atomizes the fuel

E. Distributes fuel evenly throughout the combustion chamber

V. Fuel tank maintenance problems

A. Leaks

B. Condensation

C. Dirt

VI. Air pressure testing of a fuel tank for leaks

A. Plug filler neck and attach air hose to fuel outlet

B. Submerge in clean water and apply approximately three pounds of air pressure

C. Draw a ring around each spot where bubbles appear

VII. Precautions before soldering or welding

A. Soldering--Iron should not be red hot

B. Welding

1. Plug tank outlet and fill with water

2. Leave filler cap off to allow for expansion

VIII. Types of fuel lines and purposes (Transparency 2)

A. Heavy weight (high pressure)--Transfers fuel between injection pump and injector

B. Medium weight (low pressure)--Transfers fuel between tank and injection pump

C. Light weight (no pressure)--Transfers leak-off fuel from injectors to tank or pump

IX. Purpose of fuel transfer pump

A. Draws fuel from supply tank through fuel filters

B. Forces fuel under low pressure through injection pump

INFORMATION SHEET

X. Stages of filtration (Transparency 3)

A. First stage--Filter screen at tank or transfer pump

B. Second stage--Primary filter

C. Third stage--Secondary filter

XI. Operation of dual filters (Transparency 4)

A. Series--All fuel flows through one filter before flowing through the other

B. Parallel--Part of the fuel goes through each filter

XII. Major types of injection systems

A. Common rail system

(NOTE: The common rail system is not suitable for high speed, small-bore engines because it is difficult to control the small quantities of fuel injected into the cylinder at each stroke.)

B. Accumulator system

(NOTE: The quantity of fuel injected per stroke can be varied in the accumulator system.)

C. Jerk pump system

(NOTE: Almost all modern diesel systems are of this type; therefore, type A and type B are not discussed in this unit.)

XIII. Operation of jerk pump system--Operates on the plunger and cam principle whereby the pump itself raises pressure, meters the charge, and times the injection

XIV. Pump and injection nozzle methods for injecting fuel (Transparency 5)

A. Individual pump and injection nozzle for each cylinder

(NOTE: Some engine and/or pump manufacturers who use this system are American Bosch, Robert Bosch, and C.A.V.-SIMS

B. Combined pump and injection nozzle for each cylinder (unit injector type)

(NOTE: Some engine and/or pump manufacturers who use this system are General Motors Corp. and Cummins Engine Company.)

INFORMATION SHEET

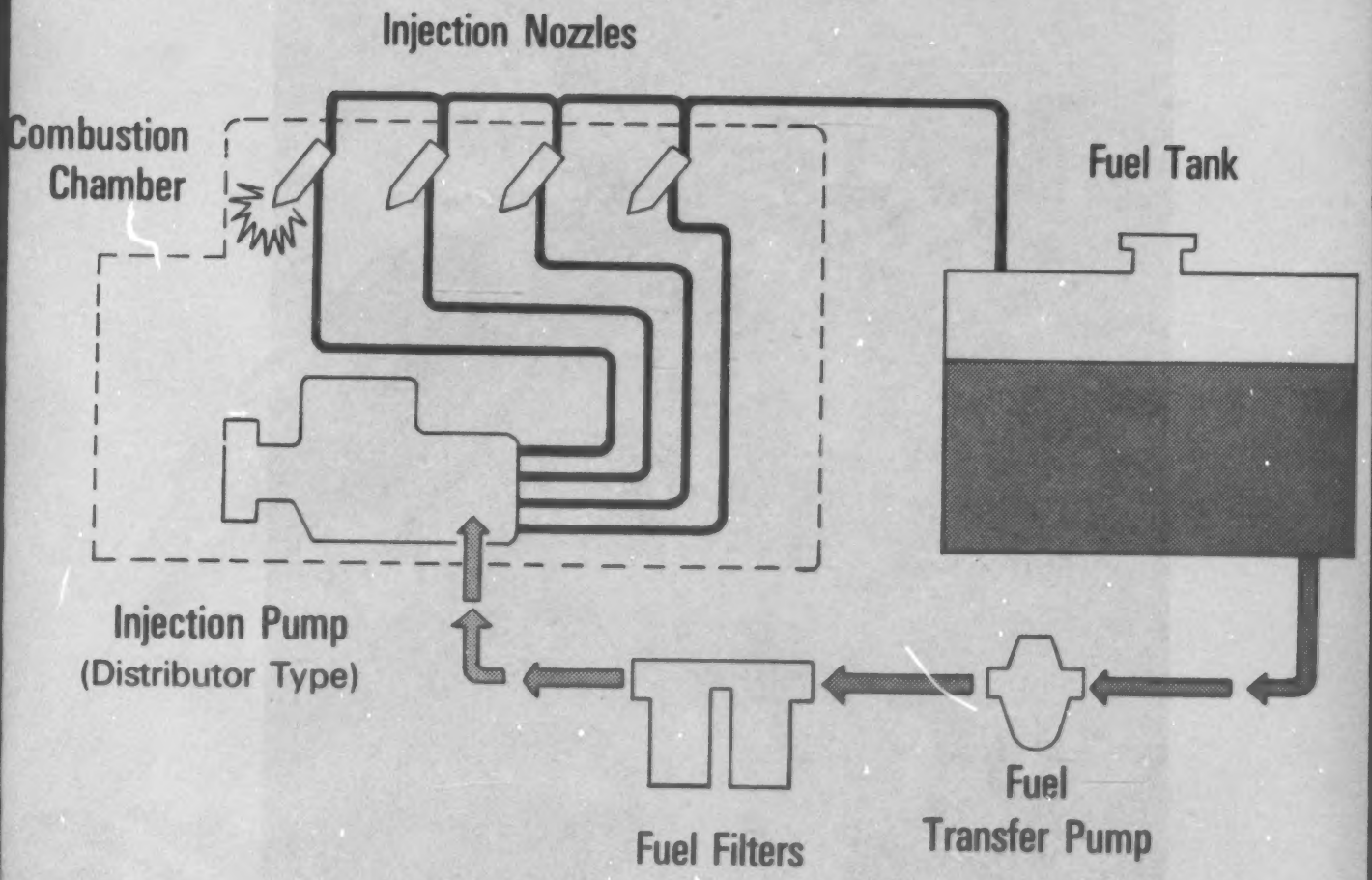
C. Pumps in common housing, injection nozzle for each cylinder (in-line type)

(NOTE: Some engine and/or pump manufacturers who use this system are Robert Bosch, models P.E.A. and P.E.S., American Bosch, Model A.P.E., C.A.V.-Sims, Caterpillar.)

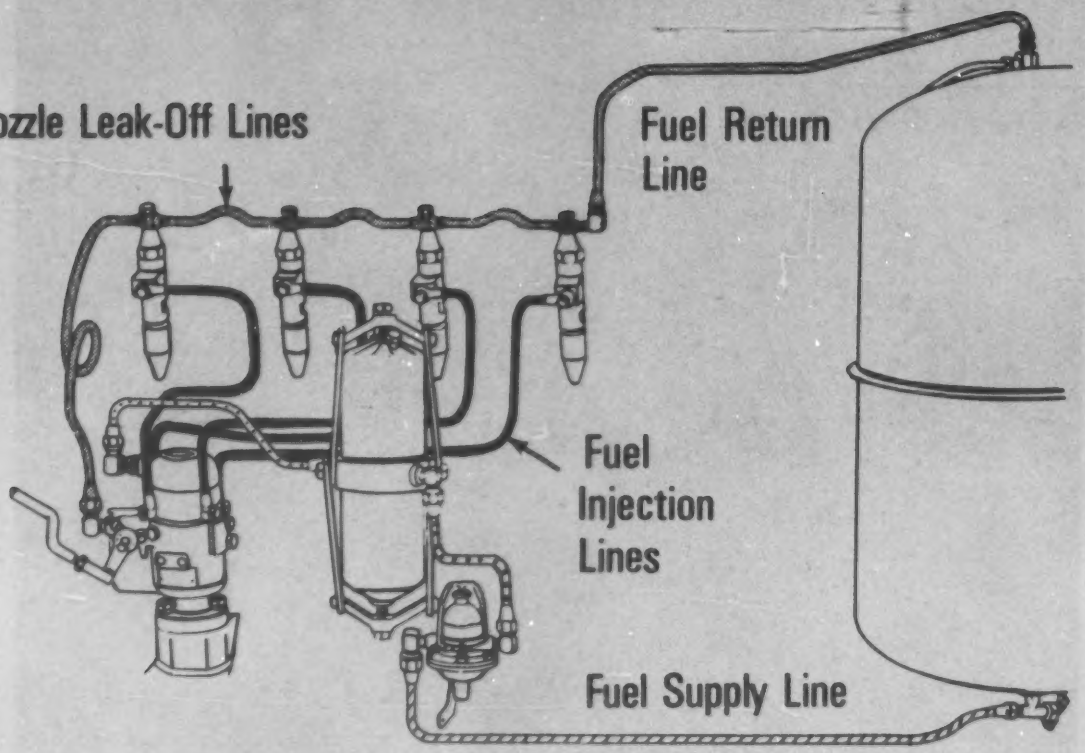
D. One pump serving injection nozzles for several cylinders (distributor type)

(NOTE: Some engine and/or pump manufacturers who use this system are: Roosa Master Models D, DB, DC, CB, and DM; American Bosch Models P.S.B., P.S.J., and 100 Series; Robert Bosch Model EP/VA; C.A.V.-D.P.A.)

Fuel System Components



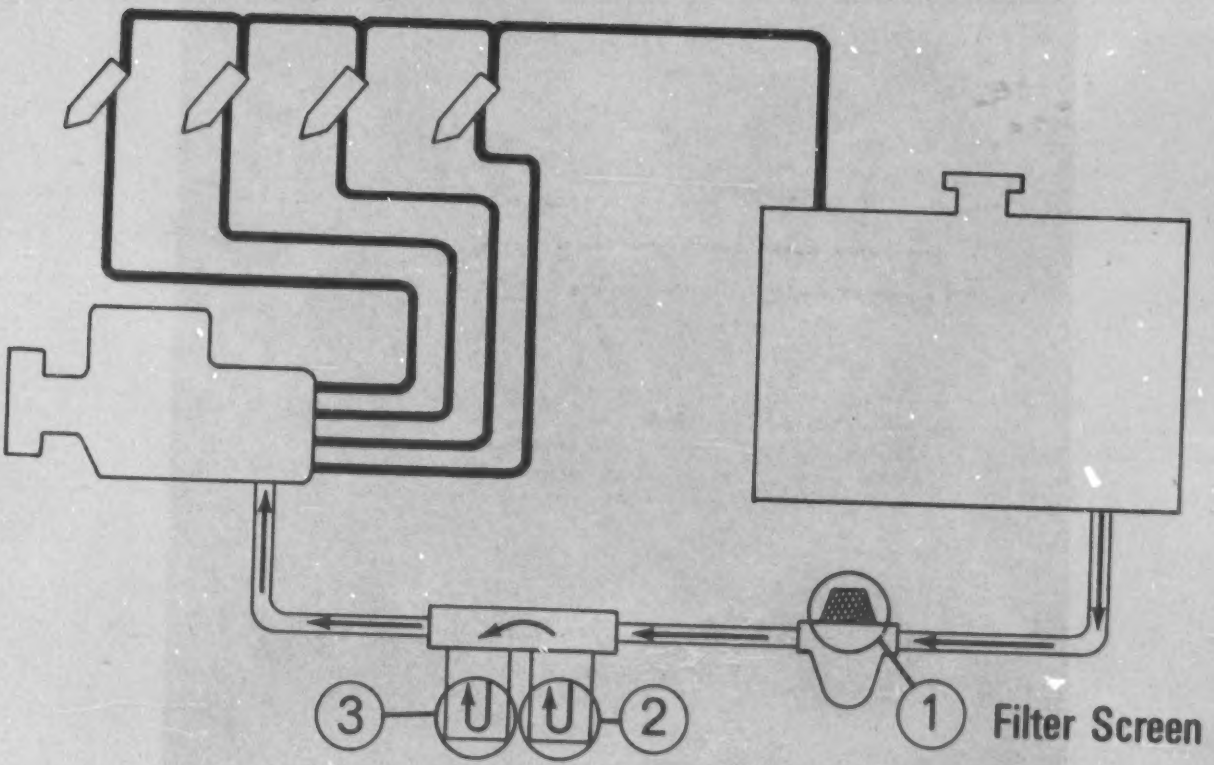
Types of Fuel Lines



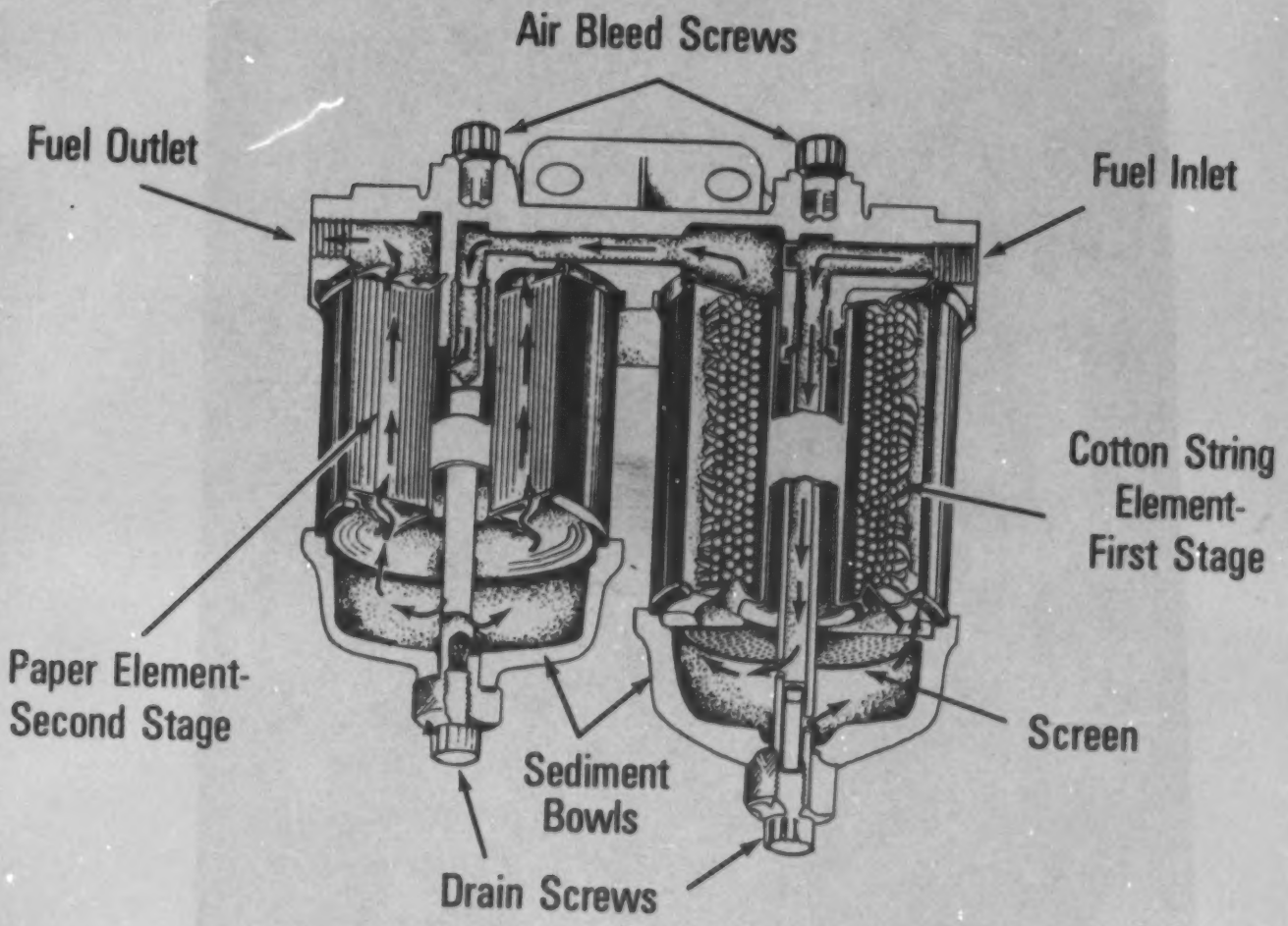
Very High Pressure Low Pressure No Pressure

Fuel Lines in a Diesel Fuel System

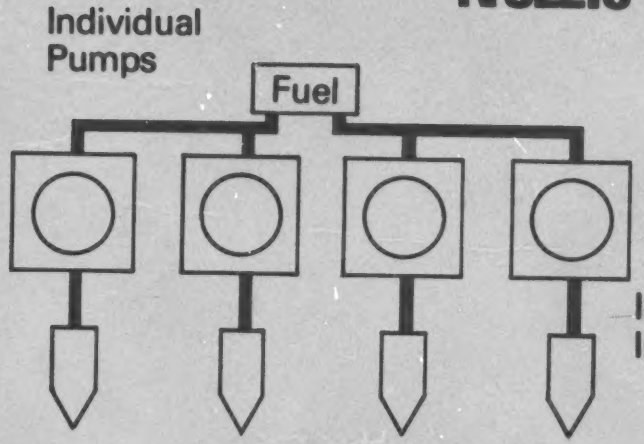
Stages of Fuel Filtration



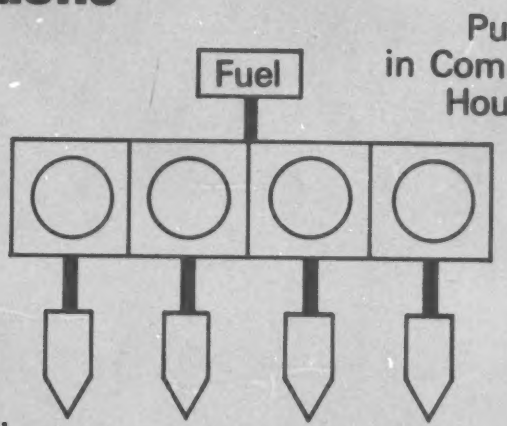
Series Dual Fuel Filters



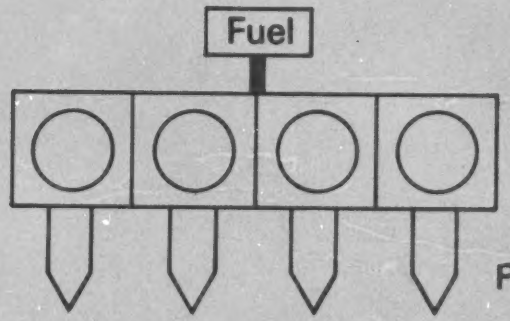
Jerk Pump and Injection Nozzle Combinations



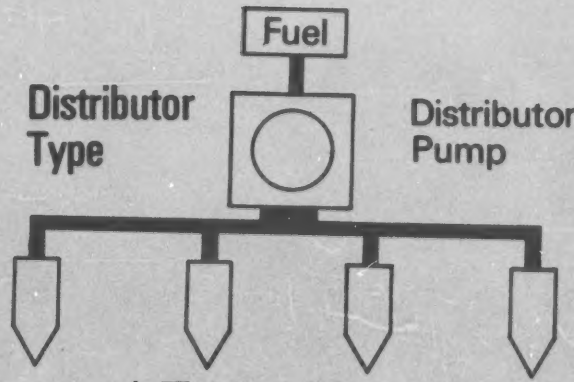
Pump and Injector-Each Cylinder



In-Line Type



Unit Injector Type



FUEL SYSTEM COMPONENTS
UNIT I

NAME _____

TEST

1. Match the terms on the right to the correct definitions.

_____a. Break down into small particles	1. Injection nozzle
_____b. Device to distribute fuel in the combustion chamber	2. Fuel pump
_____c. Pressure developing unit which supplies fuel to the injector	3. Unit injector
_____d. Pump and fuel injection nozzle combined into one unit	4. Atomize

2. Name five major parts of a fuel system.

a. _____

b. _____

c. _____

d. _____

e. _____

3. Match the parts of the fuel system on the right to their functions.

_____a. Stores fuel	1. Fuel transfer pump
_____b. Supplies fuel through filters to injection pump at low pressure	2. Fuel injection nozzle
_____c. Cleans the fuel	3. Fuel tank
_____d. Times, measures, and delivers fuel under pressure to injection nozzles	4. Fuel filter
_____e. Atomizes and sprays fuel into combustion chamber	5. Fuel injection pump

4. Select the major functions of the fuel injection system by placing an "X" in the appropriate blanks.

_____a. Transfers fuel from supply tank to injector pump

_____b. Times the fuel delivery

_____c. Atomizes the fuel

_____d. Stores excess fuel

_____e. Creates a cooling effect on the fuel

_____f. Supplies the correct quantity of fuel

_____g. Controls the delivery rate

_____h. Distributes fuel evenly throughout the combustion chamber

_____i. Delivers the fuel through low pressure fuel lines

5. Name three fuel tank maintenance problems.

a.

b.

c.

6. Discuss air pressure testing of a fuel tank for leaks.

7. List the precautions to take before soldering or welding a fuel tank.

a. Soldering

b. Welding

1)

2)

8. Match the types of fuel lines on the right to their purposes.

_____a. Transfers fuel between injection pump and injector	1. Medium weight (low pressure)
_____b. Transfers fuel between tank and injection pump	2. Light weight (no pressure)
_____c. Transfers leak-off fuel from injectors to tank or pump	3. Heavy weight (high pressure)

9. Explain the purpose of the fuel transfer pump.

10. Name three types of filters used at the stages of fuel filtration on a typical diesel fuel system.

a. First stage--

b. Second stage--

c. Third stage--

11. Distinguish between the operation of the series and parallel dual filters by placing an "X" next to the description of the parallel dual filter.

_____a. Part of the fuel goes through each filter

_____b. All fuel goes through one filter before flowing through the other

12. Name three major types of injection systems.

a.

b.

c.

13. Explain the operation of the jerk pump system.

14. List four methods of injecting fuel using the pump and injection nozzle.

a.

b.

c.

d.

FUEL SYSTEM COMPONENTS
UNIT I

ANSWERS TO TEST

1. a. 4
   b. 1
   c. 2
   d. 3
2. a. Fuel tank
   b. Fuel transfer pump
   c. Fuel filters
   d. Fuel injection pump
   e. Fuel injection nozzle
3. a. 3
   b. 1
   c. 4
   d. 5
   e. 2
4. b, c, f, g, h
5. a. Leaks
   b. Condensation
   c. Dirt
6. Discussion should include:
   a. Plug filler neck and attach air hose to fuel outlet
   b. Submerge in clean water and apply approximately three pounds of air pressure
   c. Draw a ring around each spot where bubbles appear

7. a. Soldering--Iron should not be red hot

   b. Welding

      1) Plug tank outlet and fill with water

      2) Leave filler cap off to allow for expansion

8. a. 3

   b. 1

   c. 2

9. Explanation should include:

   a. Draws fuel from supply tank through fuel filters

   b. Forces fuel under low pressure through injection pump

10. a. First stage--Filter screen at tank or transfer pump

    b. Second stage--Primary filter

    c. Third stage--Secondary filter

11. a

12. a. Common rail system

    b. Accumulator system

    c. Jerk pump system

13. Explanation should include--Operates on the plunger and cam principle whereby the pump itself raises pressure, meters the charge, and times the injection

14. a. Individual pump and injection nozzle for each cylinder

    b. Combined pump and injection nozzle for each cylinder (unit injector type)

    c. Pumps in common housing, injection nozzle for each cylinder (in-line type)

    d. One pump serving injection nozzles for several cylinders (distributor type)

DISTRIBUTOR TYPE INJECTION PUMP
UNIT II

UNIT OBJECTIVE

After completion of this unit the student should be able to identify the main parts of a distributor type pump and trace the fuel flow circuit during a complete pump cycle of a distributive type pump. The student should also be able to remove, bench test, and install a distributor type pump. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit the student should be able to:

1. Match terms associated with the distributor type pump to the correct definitions.
2. Identify the main parts of a distributor type pump.
3. Identify three rotating parts of the distributor type pump.
4. Match the major parts of the distributor type pump to their functions.
5. Discuss the principles of operation of the distributor type pump.
6. Trace the fuel flow circuit during a complete pump cycle on a distributor type pump.
7. Name three functions of the end plate.
8. Name six optional features a distributor type pump may have.
9. Demonstrate the ability to:
   a. Remove a distributor type pump from an engine.
   b. Bench test a distributor type pump.
   c. Install a distributor type pump on an engine.

DISTRIBUTOR TYPE INJECTION PUMP
UNIT II

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined in the job sheets.

G. Color code oil passages on transparency masters.

H. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete job sheets.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Distributor Type Pump
2. TM 2--Main Parts of Distributor Type Pump
3. TM 3--Fuel Flow

4. TM 4--End Plate Assembly with Transfer Pump

5. TM 5--Optional Features of a Distributor Type Pump

6. TM 6--Optional Features of a Distributor Type Pump(Continued)

D. Job sheets

1. Job Sheet #1--Remove a Distributor Type Pump from an Engine

2. Job Sheet #2--Bench Test a Distributor Type Pump

3. Job Sheet #3--Install a Distributor Type Pump on an Engine

E. Test

F. Answers to test

II. References:

A. Toboldt, Bill. *Diesel: Fundamentals, Service, Repair.* South Holland, Illinois: Goodheart-Willcox Company, 1973.

B. Kates, Edgar J., and Luck, William E. *Diesel and High Compression Gas Engines.* Chicago: American Technical Society, 1974.

C. *Fundamentals of Service: Engines.* Moline, Illinois: Deere and Company, 1972.

D. *Roosa Master: Operation and Instructional Manual: Model DC Pump.* Hartford, Connecticut: Stanadyne/Hartford Division/Roosa Master.

DISTRIBUTOR TYPE INJECTION PUMP
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Distributor type injection system--Normally uses one pump to distribute fuel to all cylinders (Transparency 1)

B. Annulus--Ring; a part, structure, or marking resembling a ring

C. Hydraulic--Operated or moved by liquid in motion

D. Registry--Oil passage that indexes with a port in a rotating head

E. Metering--Precision measurement of fuel delivery

F. Retraction--Act of drawing back

G. Servomechanism--Automatic device for controlling large amounts of power with small amounts of power as a piston moved by fluid under pressure

H. Circuit--Complete path of fuel flow

I. Delivery valve--Provides retraction of delivery line pressure causing nozzle valve to return to its seat, preventing dribble of fuel into combustion chamber

II. Main parts of distributor type pump (Transparency 2)

A. Drive shaft

B. Distributor rotor

C. Transfer pump

D. Pumping plungers

E. Internal cam-ring

F. Hydraulic head

G. End plate

H. Governor

I. Automatic advance

J. Housing

INFORMATION SHEET

III. Rotating parts of the distributor type pump (Transparency 2)

A. Drive shaft

B. Distributor rotor

C. Transfer pump blades

IV. Functions of major parts (Transparency 2)

A Drive shaft--Turns distributor rotor in the hydraulic head

B. Distributor rotor--Rotation of rotor causes pumping action of plungers which discharge fuel when passages index with appropriate passages in the hydraulic head

C. Transfer pump--Draws fuel from supply tank through inlet strainer to pump

(NOTE: Vane type pump is attached to opposite end of distributor rotor.)

D. Pumping plungers--Provide pressure to transfer fuel from rotor to hydraulic head to injection nozzles

E. Internal cam-ring--Actuates the pumping plungers

F. Hydraulic head--Contains the metering valve and the bore in which the rotor revolves

G. End plate--Houses the transfer pump pressure regulating valve and fuel strainer

H. Governor--Regulates the speed by positive mechanical linkage to metering valve

I. Automatic speed advance--Hydraulic servomechanism powered by oil pressure from the transfer pump which advances injection timing

(NOTE: Not all pumps are equipped with an automatic speed advance.)

J. Housing--Contains all component parts

V. Principles of operation of the distributor type pump (Transparency 2)

A. Drive shaft engages the distributor rotor in the hydraulic head

(NOTE: Drive end of rotor has two cylinder bores, each containing two plungers.)

INFORMATION SHEET

B. Plungers are actuated toward each other simultaneously by the internal cam ring to pump fuel

C. As rotor revolves inside hydraulic head the discharge passages in the rotor indexes with appropriate passages in the hydraulic head to lead to the injector nozzles

VI. Fuel flow circuit (Transparency 3)

A. Fuel is drawn from the supply tank into the pump through the inlet strainer by the vane type fuel transfer pump

B. Transfer pump pressure forces fuel through drilled passages in the hydraulic head into the annulus

C. Fuel flows around the annulus to top of sleeve and through connecting passages to metering valve

D. Metering valve regulates the flow of fuel into the charging ring which incorporates the charging ports

E. As the rotor revolves the twin inlet passages register with two charging ports in the hydraulic head allowing fuel to flow into the pumping cylinders

F. With further rotation the inlet passages move out of registry and the single discharge port is opened

G. The rollers contact the cam lobes forcing the plungers together

H. Fuel trapped between the plungers is then delivered through delivery valve to the nozzle

VII. Functions of end plate (Transparency 4)

A. Provides fuel inlet passages and houses pressure regulating valve

B. Covers the fuel transfer pump

C. Absorbs end thrust of drive and governor

VIII. Optional features of a distributor type pump (Transparencies 5 and 6)

A. Viscosity compensator

B. Centrifugal governor

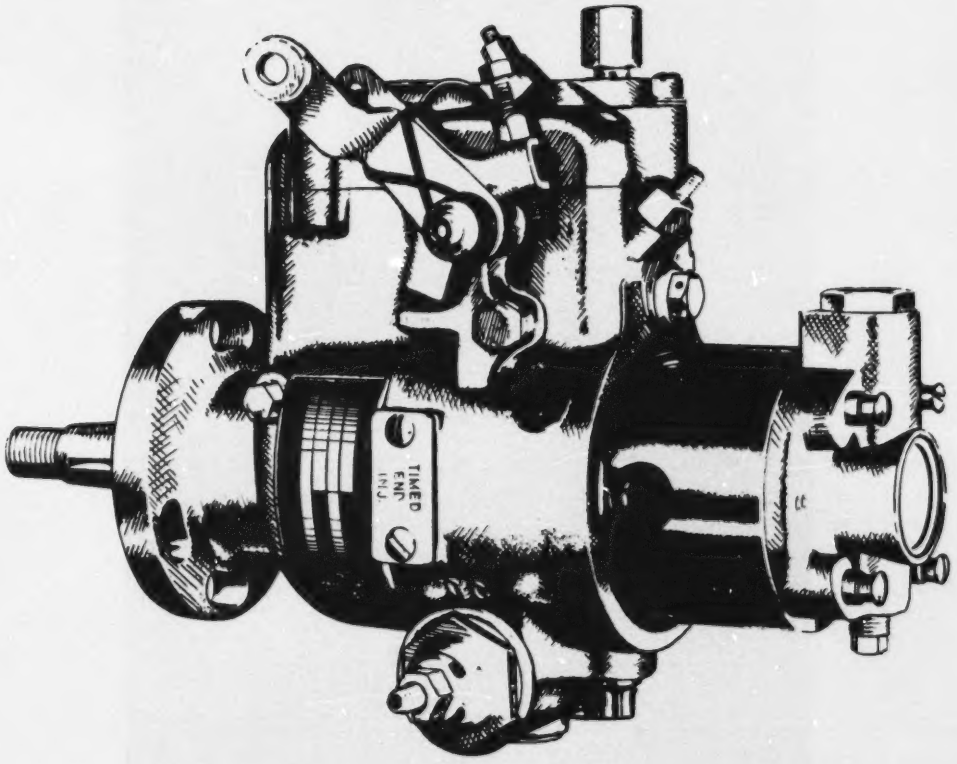
C. Automatic load advance

D. Automatic speed advance

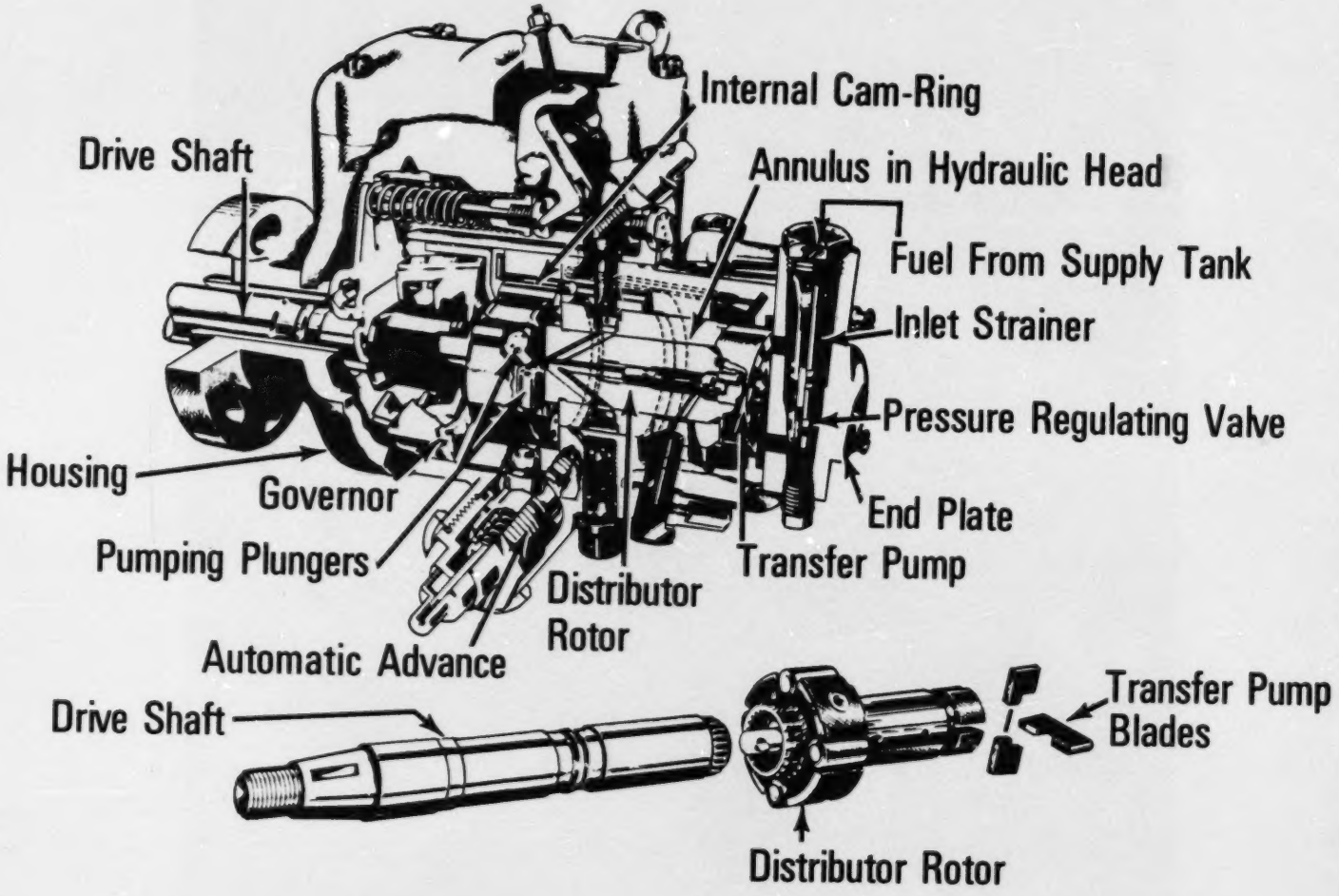
E. Torque control

F. Electric shut-off

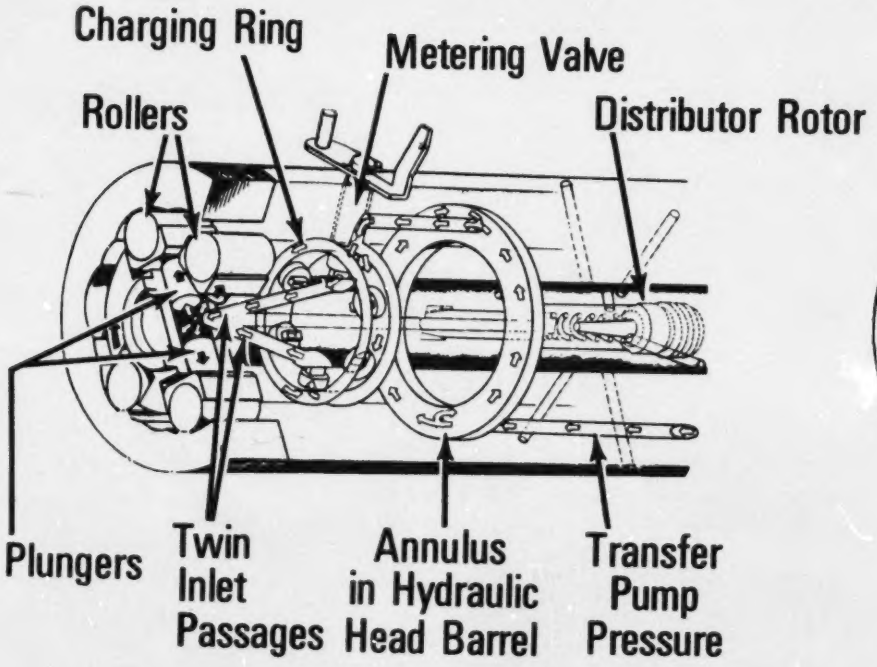
Distributor Type Pump



Main Parts of Distributor Type Pump

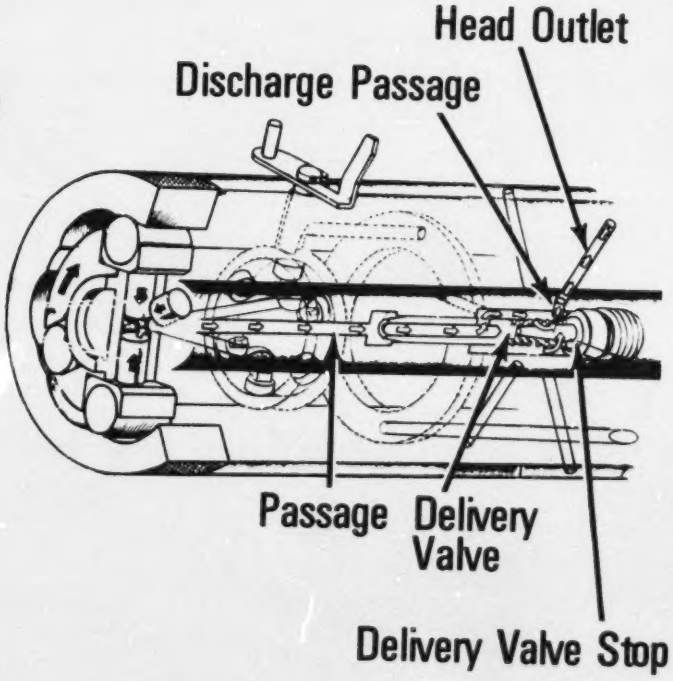


Fuel Flow



Charging Cycle

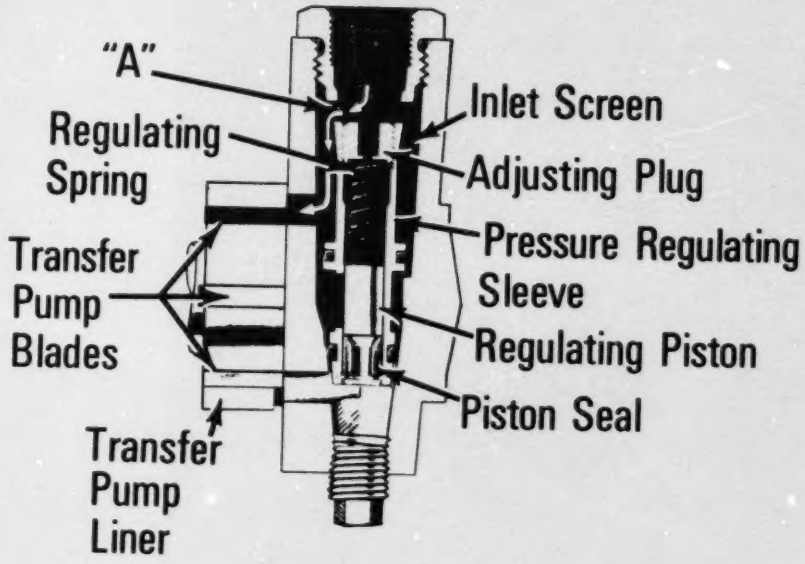
672



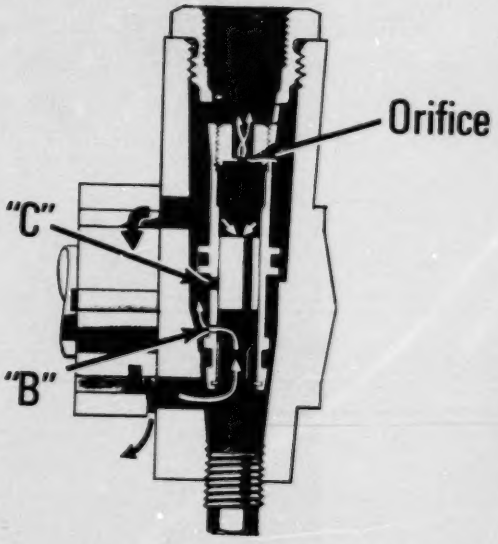
Discharge Cycle

673

End Plate Assembly with Transfer Pump

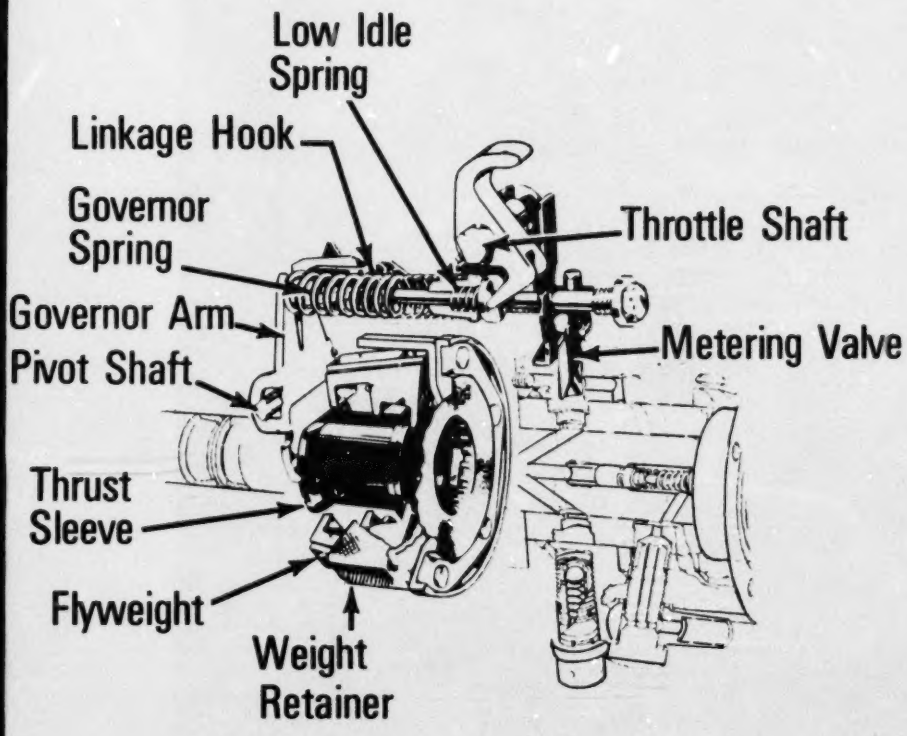


End Plate

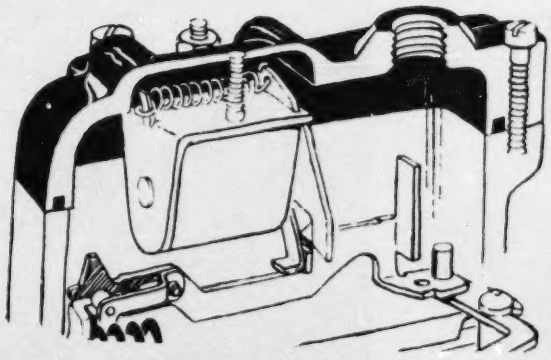


Pressure Regulating Valve

Optional Features of a Distributor Type Pump



Centrifugal Governor

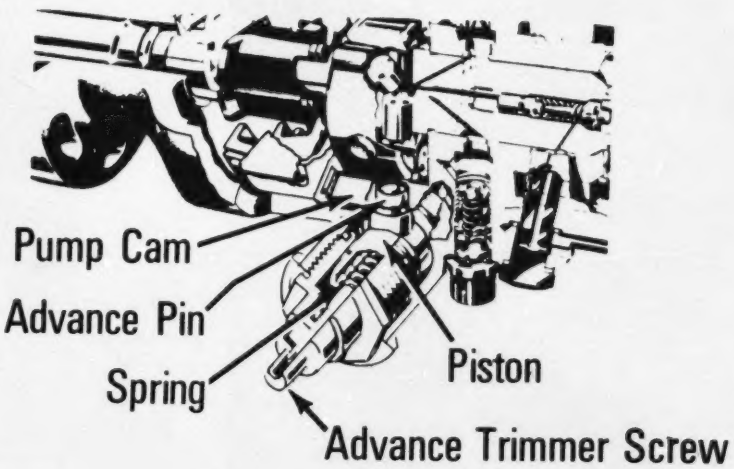


Electrical Shut-Off

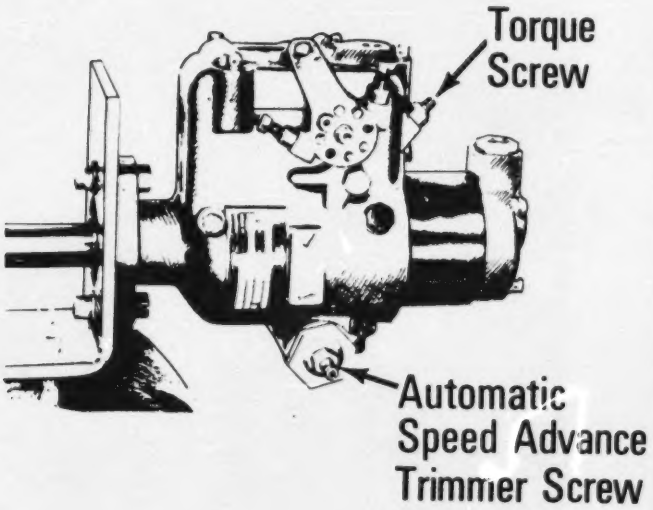
Optional Features of a Distributor Type Pump

(Continued)

Automatic Advance Mechanism



Torque Control Screw



DISTRIBUTOR TYPE INJECTION PUMP
UNIT II

JOB SHEET #1--REMOVE DISTRIBUTOR TYPE PUMP FROM ENGINE

I. Tools and materials

A. Distributor type pump

B. Appropriate service manual

C. Hand tool set

D. Solution for washing pump

E. Shop towels (lint free)

F. Shipping caps or plugs for disconnected lines

G. Safety glasses

II. Procedure

(NOTE: Refer to engine manual and determine type pump installation. If drive shaft is part of engine drive assembly it remains with the engine.)

A. Clean and wash down pump, fittings, and all connections to be broken to eliminate any chance of dirt entering the system when lines are disconnected

(CAUTION: All openings should be temporarily plugged as lines are disconnected.)

B. Check the engine manual for proper timing position of crankshaft

C. Bar the engine in correct direction of rotation until the engine timing mark is indexed and the No. 1 cylinder is on compression stroke

D. Remove the timing window cover from the outboard side of the pump

(NOTE: The timing line on the governor weight retainer hub should be directly opposite the line on the cam. Engine performance will be poor if these lines are not indexed properly.)

E. Disconnect the fuel supply, return, and nozzle leakoff lines and all high pressure lines, plugging all openings

JOB SHEET #1

F. Disconnect throttle and shut-off linkage

G. Tie throttle lever in full fuel position

H. Remove mounting nuts on the pump flange

I. Slide pump gently from location

(CAUTION: Be careful not to damage the pilot tube by cocking pump on removal.)

DISTRIBUTOR TYPE INJECTION PUMP
UNIT II

JOB SHEET #2--BENCH TEST DISTRIBUTOR TYPE PUMP

I. Tools and materials

A. Distributor type pump

B. Appropriate service manual

C. Hand tool set

D. Injection line - 1/16" I.D. x 20" length

E. Injection line - 3/32" I.D. x 20" length

F. Calibrating nozzles adjusted to pump manufacturer's specifications

G. Pump test stand

H. Adapters--pump to test stand

I. Recommended calibrating oil

J. Shop towels, lint free

K. Safety glasses

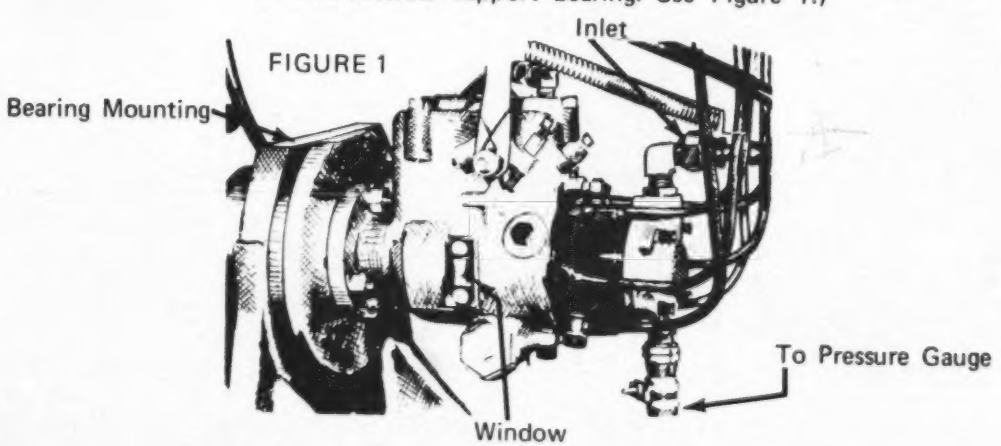
II. Procedure

A. Calibrate and test

1. Mount the pump securely with appropriate adapters

(NOTE: If pump employs a steel pilot tube, do not support the drive shaft in the housing. A drive adapter, usually with a ball bearing, supports the shaft. These pumps must be tested using an intermediate support bearing. See Figure 1.)

FIGURE 1



JOB SHEET #2

2. Install high pressure injection lines using new gaskets

   (NOTE: Install two new gaskets, one on each side of fitting. Leave fuel line connector screws at pump and injection line nuts at nozzles loose.)

3. Install inlet and return lines and transfer pump pressure gauge

   (NOTE: Use a restriction fitting on the return line if the pump normally uses one.)

4. Determine proper direction of rotation from pump name plate ("C" -- Clockwise, "CC" -- Counter-clockwise)

   (NOTE: Rotation is determined as viewed from drive end of pump.)

5. Start stand at lowest speed, move throttle to "full-load" position

6. When transfer pump picks up suction, allow fuel to bleed for several seconds from loosened connector screws

7. Allow fuel to bleed from loosened injection line nuts, then tighten securely

   (NOTE: If pump is factory tested on stands which measure fuel flow in cubic millimeters, it is necessary to convert the readings on other types of stands which measure in cubic centimeters. See Figure 2.)

FIGURE 2

Delivery In Each Graduate (CC's)	Delivery in Cubic Millimeters (MM^3) per Stroke								
	Numbered Strokes								
	25	100	125	200	250	300	400	500	1000
1	40	10	8	5	4	3.3	2.5	2	1 (mm^3)
2	80	20	16	10	8	6.7	5.0	4	2
3	120	30	24	15	12	10.0	7.5	6	3
4	160	40	32	20	16	13.3	10.0	8	4
5	200	50	40	25	20	16.7	12.5	10	5
6	240	60	48	30	24	20.0	15.0	12	6
7	280	70	56	35	28	23.3	17.5	14	7
8	320	80	64	40	32	26.7	20.0	16	8
9	360	90	72	45	36	30.0	22.5	18	9
10	400	100	80	50	40	33.3	25.0	20	10
20		200	160	100	80	66.7	50.0	40	20
30		300	240	150	120	100.0	75.0	60	30
40		400	320	200	160	133.3	100.0	80	40
50			400	250	200	166.7	125.0	100	50
60				300	240	200.0	150.0	120	60
70					280	233.3	175.0	140	70
80					320	266.7	200.0	160	80
90					360	300.0	225.0	180	90
100					400	333.3	250.0	200	100

JOB SHEET #2

(NOTE: The test stand tachometer registers pump speed. Some specification test data refers to engine speed.)

8. Operate pump at 1000 RPM for 10 minutes

9. Dry off completely with compressed air

10. Observe for leaks and correct as necessary

11. Back out the high idle stop screw and torque screw (if equipped)

(NOTE: The inlet to the transfer pump should never be pressurized during bench testing.)

12. Close valve in supply line

(NOTE: Check to see that transfer pump pulls up to manufacturer's specifications. If it does not, check for air leaks on suction side or malfunction of end plate and transfer pump parts. If the pump is equipped with an external by-pass, it should be pinched off during this test.)

13. Fill graduates to bleed air from test stand and to wet glass

14. Observe return oil

(NOTE: Compare observable return with manufacturer's specifications. By-pass equipped pumps will return less fuel.)

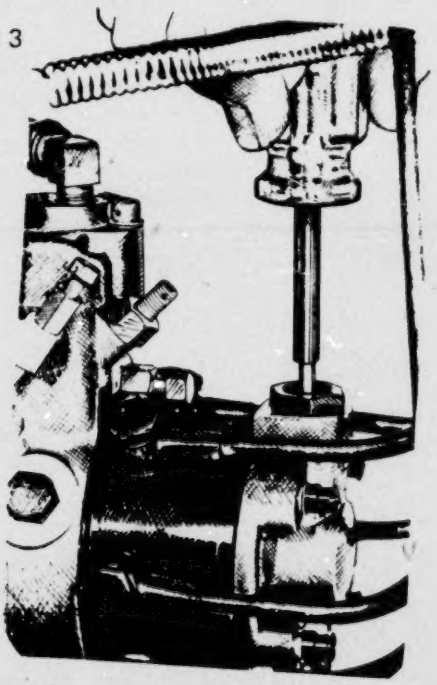
JOB SHEET #2

15. Operate the specified speeds with wide open throttle and observe transfer pump pressure

(NOTE: Adjust pressure regulating spring plug to raise or lower transfer pump pressure.)

(CAUTION: Under no circumstances should 130 psi be exceeded. See Figure 3.)

FIGURE 3



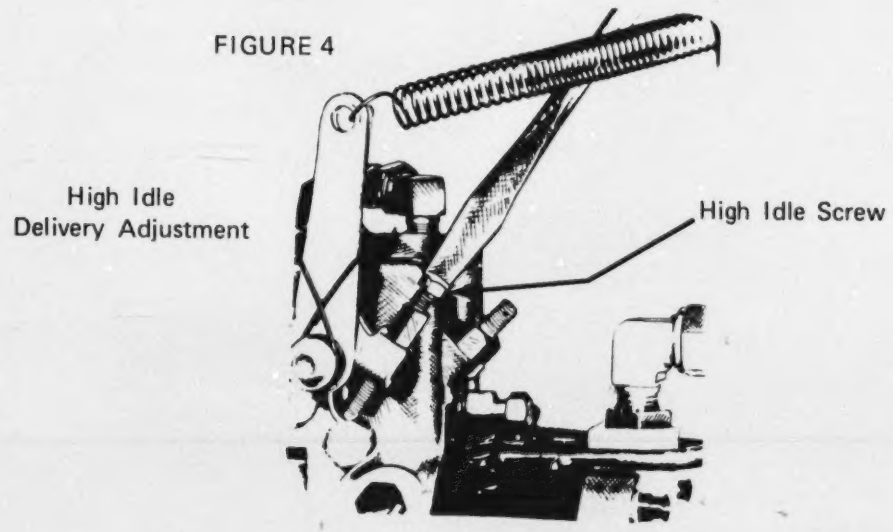
Transfer Pump Pressure Adjustment

16. Check for minimum delivery at cranking speed

JOB SHEET #2

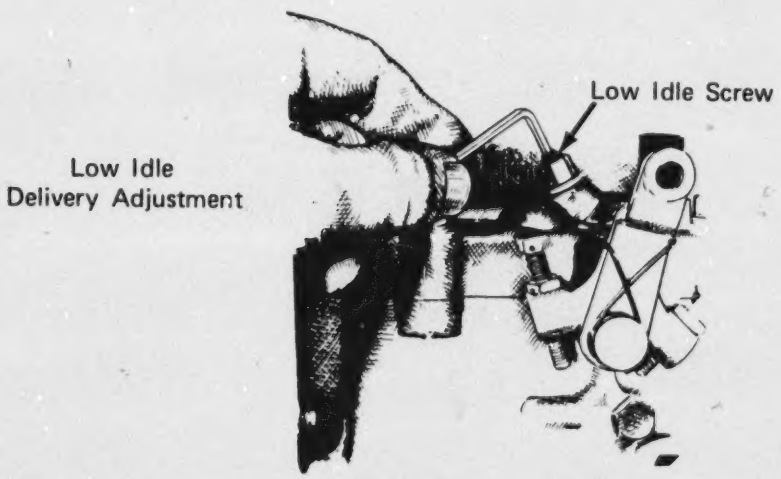
17. Operate at high idle speed and adjust high idle screw to obtain the specified delivery (Figure 4)

FIGURE 4



18. Adjust the low idle screw to the correct low idle delivery (Figure 5)

FIGURE 5



JOB SHEET #2

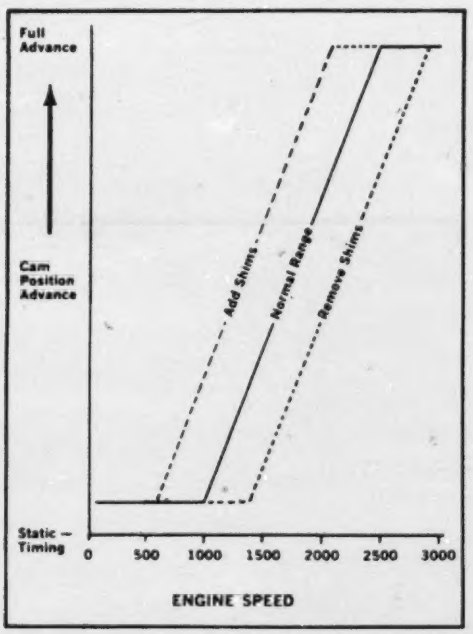
19. Adjust automatic advance

a. Adjust speed advance

1) Check the cam position at specified points in the speed range

2) Adjust trimmer screw, or shim, as required to obtain proper advance operation (Figure 6)

FIGURE 6



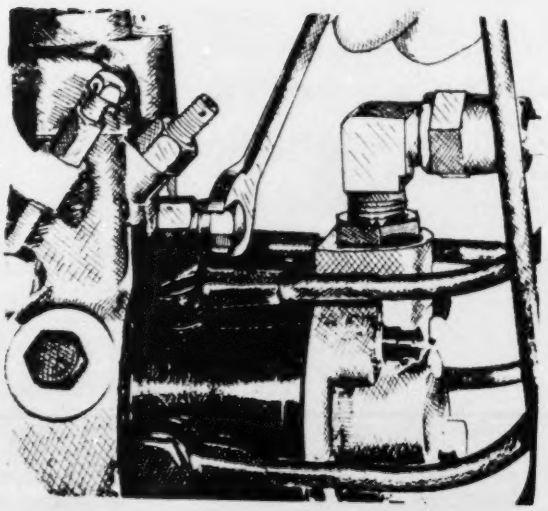
b. Adjust load advance

1) Adjust the test stand speed to the specified part-load delivery

JOB SHEET #2

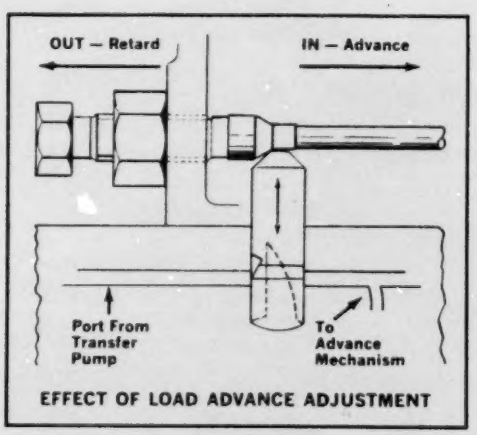
2) Observe cam position and adjust guide stud for correct cam movement (Figures 7 and 8)

FIGURE 7



Load Advance Adjustment

FIGURE 8



EFFECT OF LOAD ADVANCE ADJUSTMENT

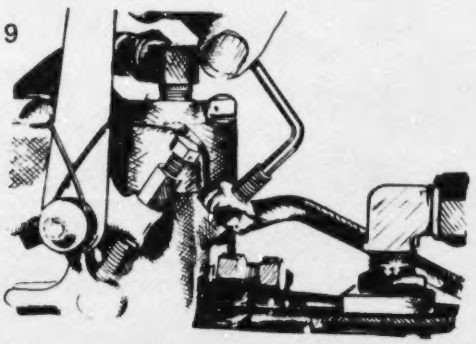
20. Record fuel delivery at check points shown on the pump specification

(NOTE: ROLLER SETTINGS SHOULD NOT BE READJUSTED ON THE TEST BENCH. Experience has proven that micrometer and dial indicator settings provide more consistent, accurate results in performance. Variations in test benches, nozzles, lines, and fuels in different areas sometime result in inaccurate flow readings.)

JOB SHEET #2

21. While operating at full-load governed speed set torque screw (if employed) to specified delivery (Figure 9)

FIGURE 9



Torque Screw Adjustment

22. Recheck delivery at lowest speed checkpoint

23. Check governor cutoff at specified speed

24. Remove from test stand and assemble all sealing wires; pump is now ready for installation to engine

(NOTE: If there is no drive shaft with the pump, wire the throttle lever in "full fuel" position for shipment or until installed on engine. Otherwise, mount the pump on drive adaptor with shaft. Check shaft seals with a pressure test on the housing.)

DISTRIBUTOR TYPE INJECTION PUMP
UNIT II

JOB SHEET #3--INSTALL DISTRIBUTOR TYPE PUMP ON ENGINE

I. Tools and materials

A. Distributor type pump

B. Appropriate service manual

C. Drive shaft installation tool

D. Torque wrench

E. Safety glasses

II. Procedure

(NOTE: Pumps marked "Timed Start Inj." or "Timed End Inj." on the timing window cover are timed according to procedures below.)

A. Remove outboard timing window cover (name plate side)

B. With a CLEAN wide bladed screwdriver or the pump drive shaft inserted into the drive end of the pump, rotate the distributor rotor until the timing line on the weight retainer hug registers with the line on the cam O.D.

(NOTE: The pump is now correctly positioned for assembly to the engine.)

C. Roll the engine in direction of rotation until the flywheel is correctly positioned for fuel pump assembly (See engine manual)

D. Apply a light coat of grease to the drive shaft seals

E. While compressing the drive shaft seals with the drive shaft installation tool, slide the pump into position over the mounting studs

(NOTE: Make sure drive shaft and seals are properly positioned.)

F. Assemble and tighten the mounting nuts finger tight

JOB SHEET #3

G. Rotate pump, first in the direction of rotation and then in the opposite direction until timing lines again register (Figures 1 and 2)

FIGURE 1

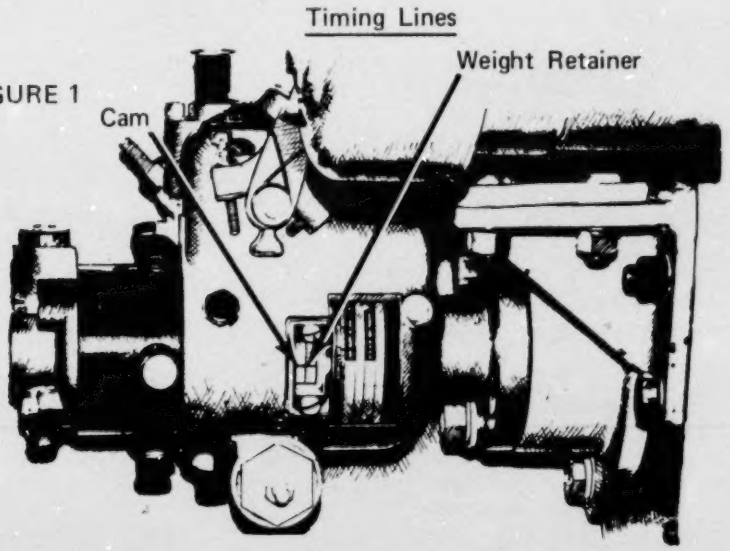
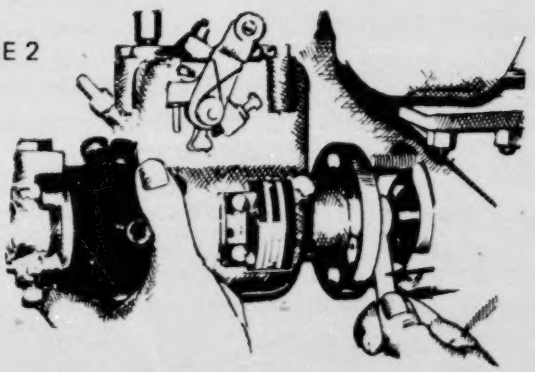


FIGURE 2



H. To take up all back lash, tighten nuts securely

(CAUTION: Drive shaft spline should engage with hand pressure. Do not attempt to "draw up" the pump flange with mounting stud nuts. If spline does not engage, rotate pump slightly to locate timing pin.)

JOB SHEET #3

I. Back off engine at least 1/2 revolution and roll it again in the direction of rotation to the proper timing mark

(NOTE: Recheck line marks in the pump and correct if necessary. Repeat procedure to insure proper timing.)

J. Unplug open ends of high pressure lines, assemble with new fuel line connector washers and tighten to specified torque

K. Assemble and tighten fuel return and nozzle leak-off lines

L. Attach pump controls

M. Open bleed screw on secondary filter, and operate hand primer (if equipped) or allow fuel to flow from tank until all air is dispelled from filter

N. Close bleed screw

O. Continue hand priming until a quantity of fuel flows "air-free" at pump inlet line

P. Fasten the inlet line to the pump

(NOTE: This procedure should also be followed without fail after every filter change. Refer to engine manual for starting instructions before starting engine.)

Q. Provide means for emergency shut-off

DISTRIBUTOR TYPE INJECTION PUMP
UNIT II

NAME_____

TEST

1. Match the terms on the right to the correct definitions.

_____a. Ring; a part, structure, or marking resembling a ring

_____b. Operated or moved by liquid in motion

_____c. Oil passage that indexes with a port in a rotating head

_____d. Act of drawing back

_____e. Automatic device for controlling large amounts of power with small amounts of power as a piston moved by fluid under pressure

_____f. Complete path of fuel flow

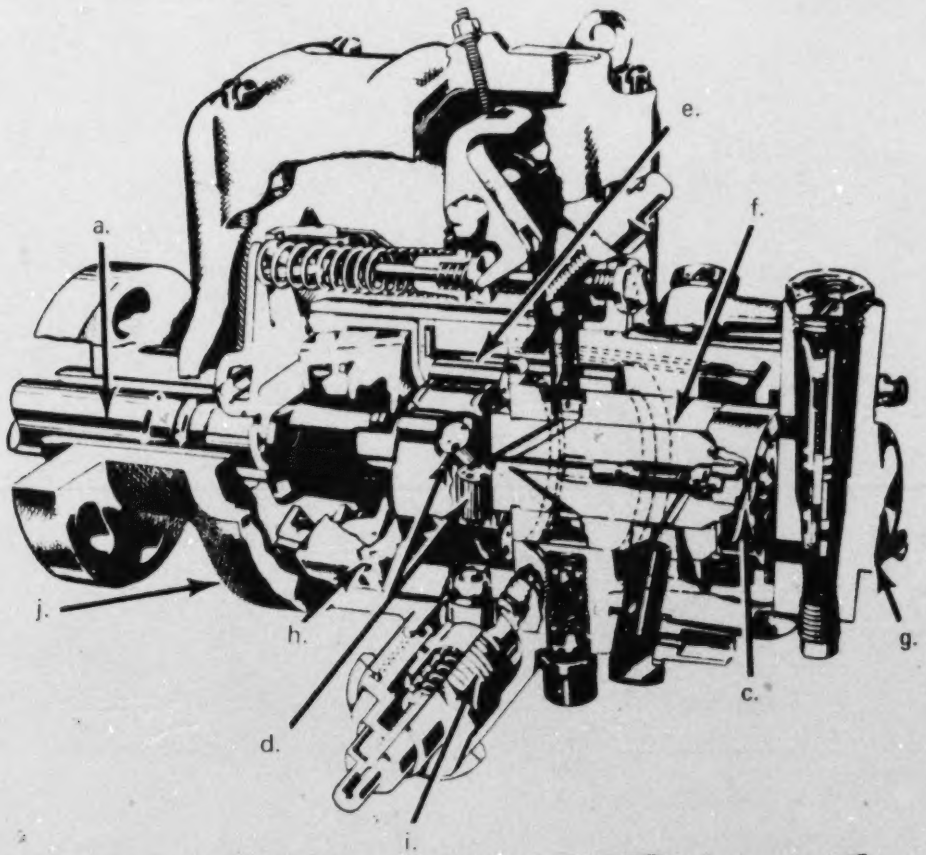
_____g. Normally uses one pump to distribute fuel to all cylinders

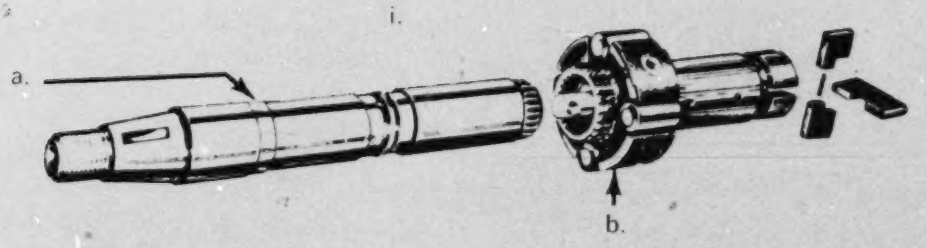
_____h. Provides retraction of delivery line pressure causing nozzle valve to return to its seat, preventing dribble of fuel into combustion chamber

_____i. Precision measurement of fuel delivery

1. Hydraulic
2. Distributor type injection system
3. Retraction
4. Circuit
5. Servomechanism
6. Annulus
7. Registry
8. Metering
9. Delivery valve

2. Identify the main parts of a distributor type pump.





a. _____ f. _____

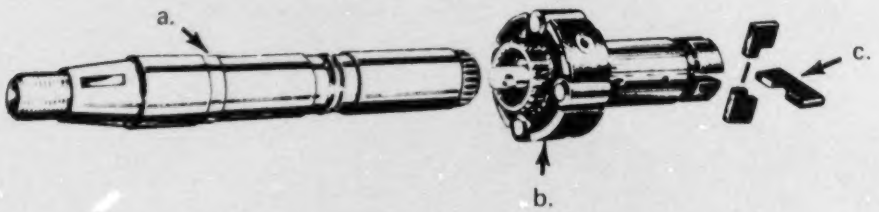
b. _____ g. _____

c. _____ h. _____

d. _____ i. _____

e. _____ j. _____

3. Identify three rotating parts of the distributor type pump.



a. _____

b. _____

c. _____

4. Match the major parts of the distributor type pump on the right to their functions.

_____a. Turns distributor rotor in the hydraulic head

_____b. Rotation of rotor causes pumping action of plungers which discharge fuel when passages index with appropriate passages in the hydraulic head

_____c. Draws fuel from supply tank through inlet strainer to pump

_____d. Provide pressure to transfer fuel from rotor to hydraulic head to injection nozzles

_____e. Actuates the pumping plungers

_____f. Contains the metering valve and the bore in which the rotor revolves

_____g. Houses the transfer pump pressure regulating valve and fuel strainer

_____h. Regulates the speed by positive mechanical linkage to metering valve

_____i. Hydraulic servomechanism powered by oil pressure from the transfer pump which advances injection timing

_____j. Contains all component parts

1. Pumping plungers
2. Drive shaft
3. Distributor rotor
4. Housing
5. Hydraulic head
6. Automatic speed advance
7. Governor
8. Internal cam-ring
9. Transfer pump
10. End plate

5. Discuss the principles of operation of the distributor type pump.

6. Trace the fuel flow circuit during a complete pump cycle on a distributor type pump.

   a.

   b.

   c.

   d.

   e.

   f.

   g.

7. Name three functions of the end plate.

   a.

   b.

   c.

8. Name six optional features a distributor type pump may have.

   a.

   b.

   c.

d.

e.

f.

9. Demonstrate the ability to:

   a. Remove a distributor type pump from an engine.

   b. Bench test a distributor type pump.

   c. Install a distributor type pump on an engine.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

DISTRIBUTOR TYPE INJECTION PUMP
UNIT II

ANSWERS TO TEST

1. a. 6
   b. 1
   c. 7
   d. 3
   e. 5
   f. 4
   g. 2
   h. 9
   i. 8
2. a. Drive shaft
   b. Distributor rotor
   c. Transfer pump
   d. Pumping plungers
   e. Internal cam-ring
   f. Hydraulic head
   g. End plate
   h. Governor
   i. Automatic advance
   j. Housing
3. a. Drive shaft
   b. Distributor rotor
   c. Transfer pump blades
4. a. 2
   b. 3
   c. 9
   d. 1
   e. 8
   f. 5
   g. 10
   h. 7
   i. 6
   j. 4

5. Discussion should include:

   a. Drive shaft engages the distributor rotor in the hydraulic head

   b. Plungers are actuated toward each other simultaneously by the internal cam-ring to pump fuel

   c. As rotor revolves inside hydraulic head the discharge passages in the rotor indexes with the appropriate passages in the hydraulic head to lead to the injector nozzles

6. a. Fuel is drawn from supply tank into the pump through the inlet strainer by the vane type fuel transfer pump

   b. Transfer pump pressure forces fuel through drilled passages in the hydraulic head into the annulus

   c. Fuel flows around the annulus to top of sleeve and through connecting passages to metering valve

   d. Metering valve regulates the flow of fuel into the charging ring which incorporates the charging ports

   e. As the rotor revolves the twin inlet passages register with two charging ports in the hydraulic head allowing fuel to flow into the pumping cylinders

   f. With further rotation the inlet passages move out of registry and the single discharge port is opened

   g. The rollers contact the cam lobes forcing the plungers together

   h. Fuel trapped between the plungers is then delivered through delivery valve to the nozzle

7. a. Provides fuel inlet passages and houses pressure regulating valve

   b. Covers the fuel transfer pump

   c. Absorbs end thrust of drive and governor

8. a. Viscosity compensator

   b. Centrifugal governor

   c. Automatic load advance

   d. Automatic speed advance

   e. Torque control

   f. Electric shut-off

9. Performance skills evaluated to the satisfaction of the instructor

IN-LINE INJECTION PUMP
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to match the main parts of an in-line injection pump and discuss the principle of operation during one complete cycle of the fuel circuit. The student should be able to bench test an in-line injection pump. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with the in-line pump to the correct definitions.
2. Match the main parts of the in-line pump to the correct name.
3. Trace the fuel flow from supply tank to delivery.
4. State the purpose of the hand primer.
5. Explain the purpose of the fuel transfer pump.
6. Discuss the operation of the injection pump.
7. Identify parts and design features of the pumping element.
8. Explain the operation of the control rack and sleeve.
9. State the purpose of the delivery valve.
10. Identify the plunger and rack positions.
11. Demonstrate the ability to bench test an in-line injection pump.

IN-LINE INJECTION PUMP
UNIT III

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information sheet.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined in the job sheet.

G. Demonstrate and discuss the procedures on assembly and reassembly of an in-line pump.

H. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete job sheet.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--In-Line Injection Pump
2. TM 2--Main Pump Parts
3. TM 3--Fuel Flow

4. TM 4--Injection Pump Operation

5. TM 5--Parts and Design of Pumping Element

6. TM 6--Control Rack and Sleeve

7. TM 7--Plunger Positions at Fuel Delivery

D. Job Sheet #1--Bench Test an In-Line Injection Pump

E. Test

F. Answers to test

II. References:

A. Toboldt, Bill. *Diesel: Fundamentals, Service, Repair.* South Holland, Illinois: Goodheart-Willcox Company, 1973.

B. Kates, Edgar J., and Luck, William E. *Diesel and High Compression Gas Engines.* Chicago: American Technical Society, 1974.

C. *Fundamentals of Service: Engines.* Moline, Illinois: Deere and Company, 1972.

D. *Technical Manual: John Deere Fuel Injection Equipment - Robert Bosch.* Moline Illinois: Deere and Company, April 1974.

IN-LINE INJECTION PUMP
UNIT III

INFORMATION SHEET

I. Terms and definitions

A. In-line injection pump--Uses an individual pump for each cylinder with pumps mounted in-line (Transparency 1)

B. Annular groove--Machined recess forming a ring on pumping plunger

C. Vertical slot--Located at right angles to the plane of the supporting surface

D. Helix--Spiraled, machined recess on pumping plunger

E. Gallery--Long, narrow fuel or oil passage

F. Aneroid--Device which limits fuel supply to engine, preventing excess smoke

G. Transfer pump (supply pump)--Sends fuel at low pressure through filters to the injection pump

II. Main parts of in-line pump (Transparency 2)

A. Aneroid

B. Individual pumping element

C. Injection line

D. Leak-off line

E. Pump housing

F. Hand primer

G. Sediment bowl

H. Fuel transfer pump

I. Camshaft

J. Control rack

K. Governor

INFORMATION SHEET

III. Fuel flow from supply tank to delivery (Transparency 3)

A. Fuel is drawn from supply tank through primary filter by fuel transfer pump

B. Transfer pump forces fuel under low pressure through secondary filter and through final stage filter to each injection pumping element

C. Pumping element meters fuel at high pressure to each injection nozzle for delivery to combustion chamber

IV. Purpose of hand primer--Hand primer on the fuel transfer pump can be operated by hand to pump fuel when bleeding the system (Transparency 4)

V. Purpose of fuel transfer pump

A. Draws fuel from supply tank through primary filter

B. Assures fuel supply to injection pumping elements

(NOTE: All fuel flows through a preliminary filter in the transfer pump sediment bowl.)

VI. Injection pump operation (Transparency 4)

A. Plunger type pump has engine driven camshaft rotating at half engine speed

B. Roller cam followers, riding on cam lobes, operate the plungers to supply high pressure fuel through delivery valves to injection nozzles

VII. Parts and design features of pumping element (Transparency 5)

A. Spill ports

B. Plunger

C. Annular groove

D. Barrel

E. Helix

F. Vertical slot

VIII. Operation of control rack and sleeve (Transparency 6)

A. Governor moves rack to regulate speed of engine

B. The sleeve, rotated by the control rack, is fitted over the barrel and connects to the vanes on the plunger

INFORMATION SHEET

C. Plunger rotation opens or closes the helix which meters the quantity of fuel for delivery to cylinder

IX. Purpose of delivery valve--The delivery valve creates a sudden pressure drop in the delivery line causing the injector nozzle valve to close instantly (Transparency 6)

(NOTE: This effect prevents dribbling at the nozzle.)

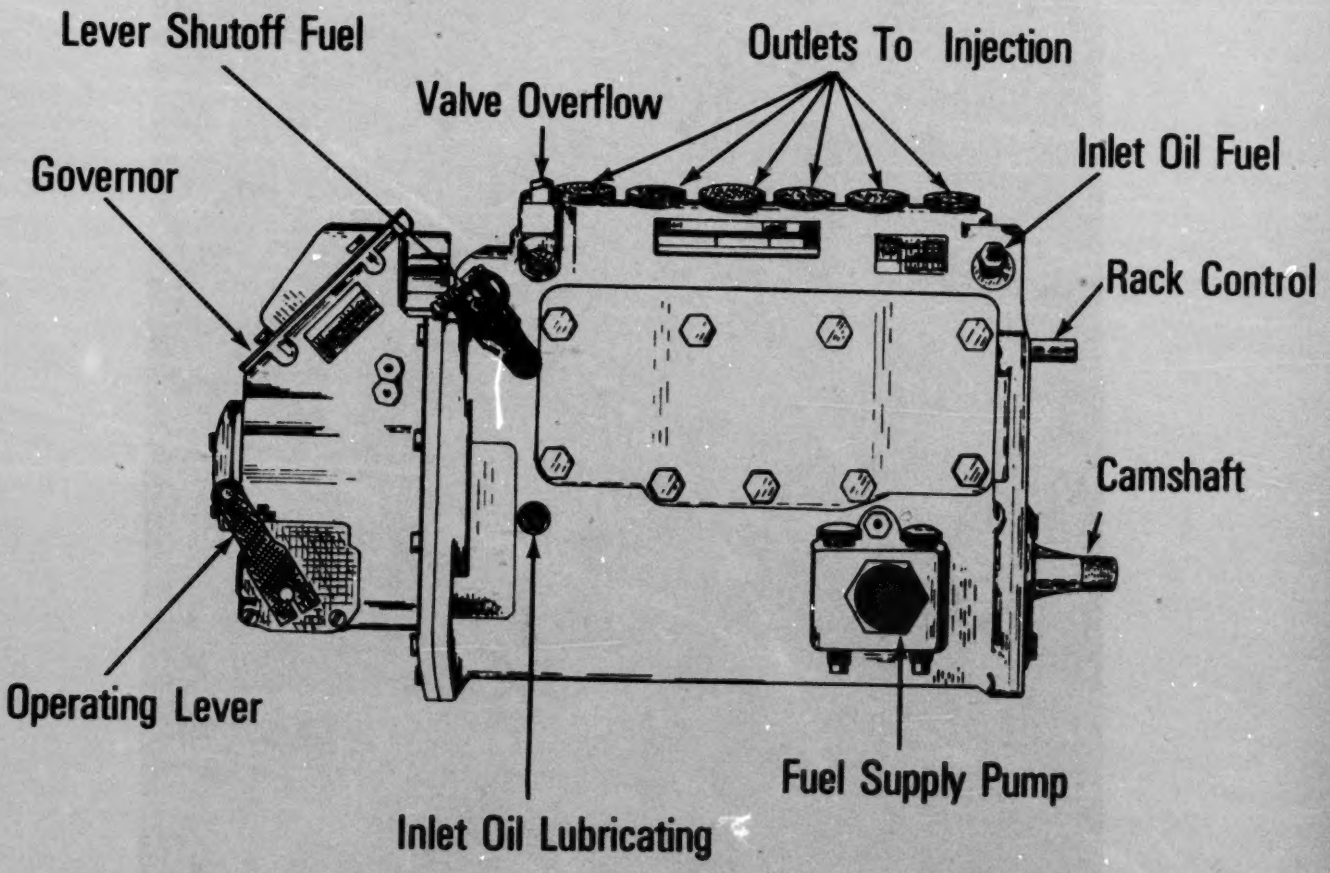
X. Plunger and rack positions (Transparency 7)

A. No fuel delivery

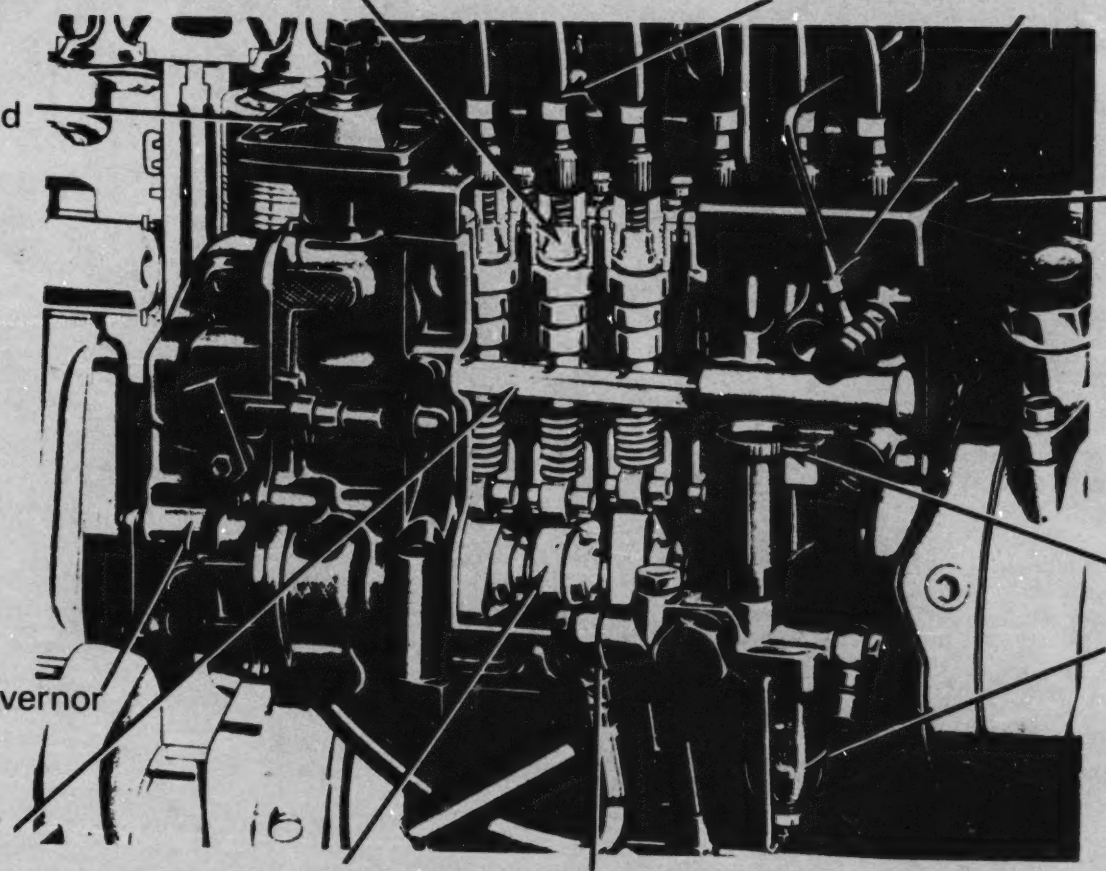
B. Partial fuel delivery

C. Full fuel delivery

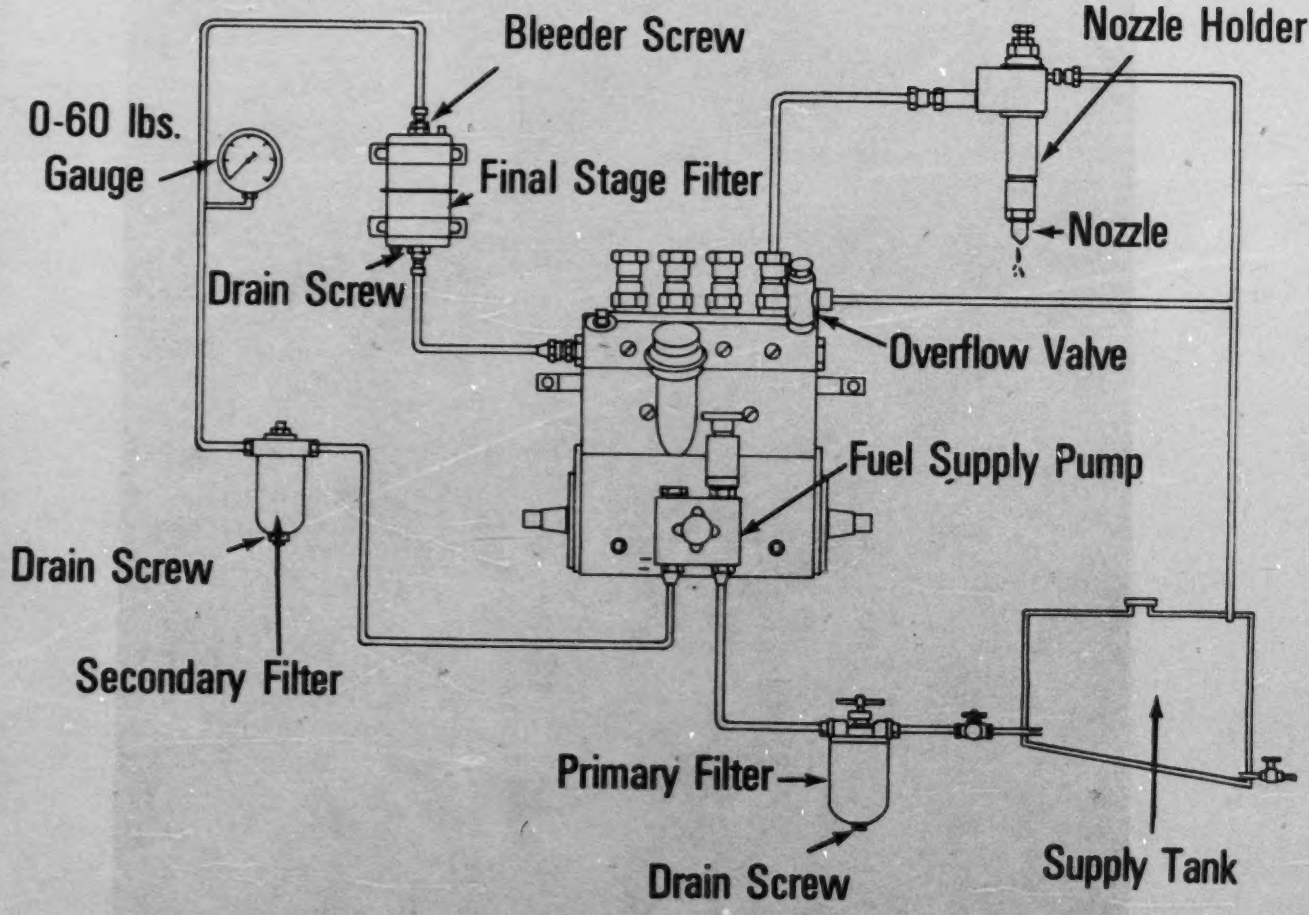
In-Line Injection Pump



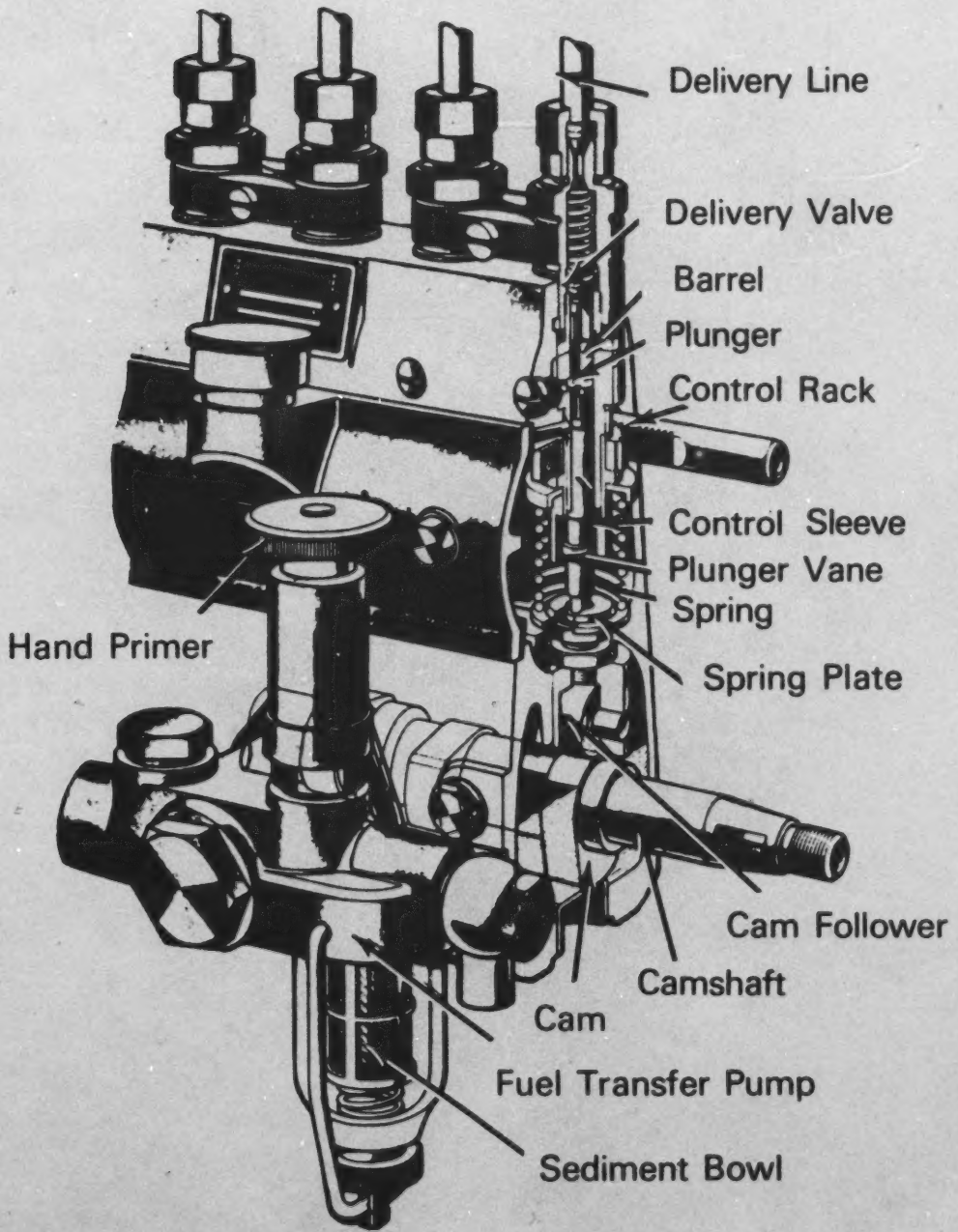
Main Pump Parts



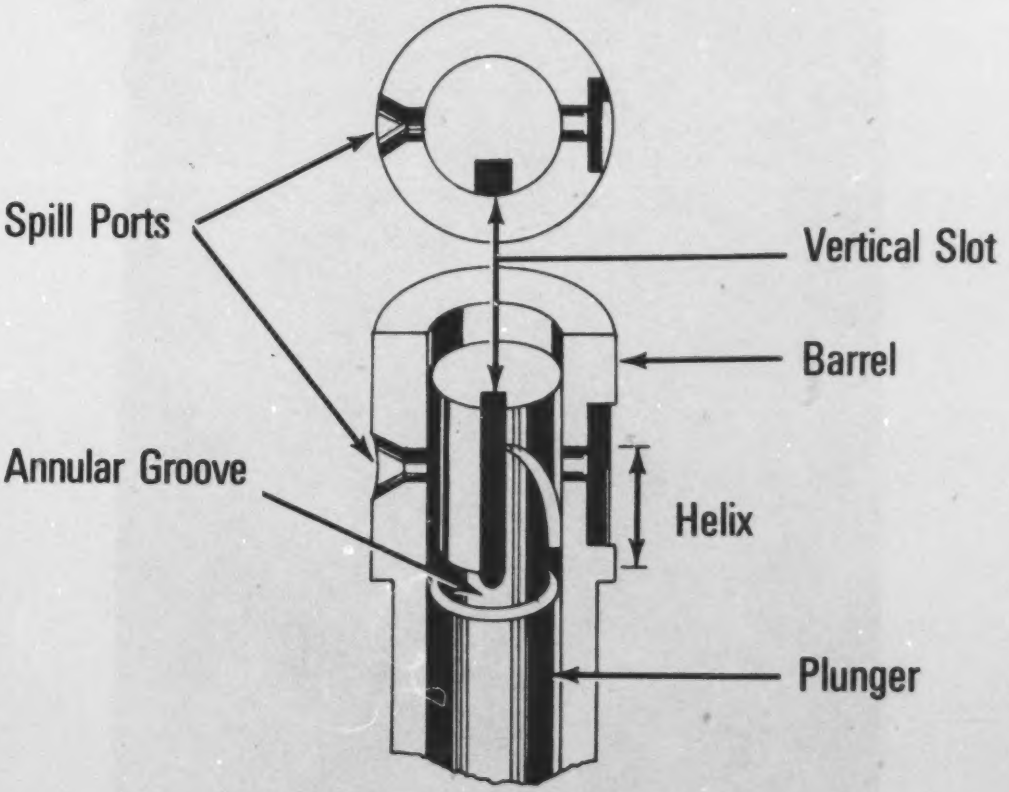
Fuel Flow


Bleeder Screw
Nozzle Holder
0-60 lbs.
Gauge
Final Stage Filter
Nozzle
Drain Screw
Overflow Valve
Fuel Supply Pump
Drain Screw
Secondary Filter
Primary Filter
Drain Screw
Supply Tank

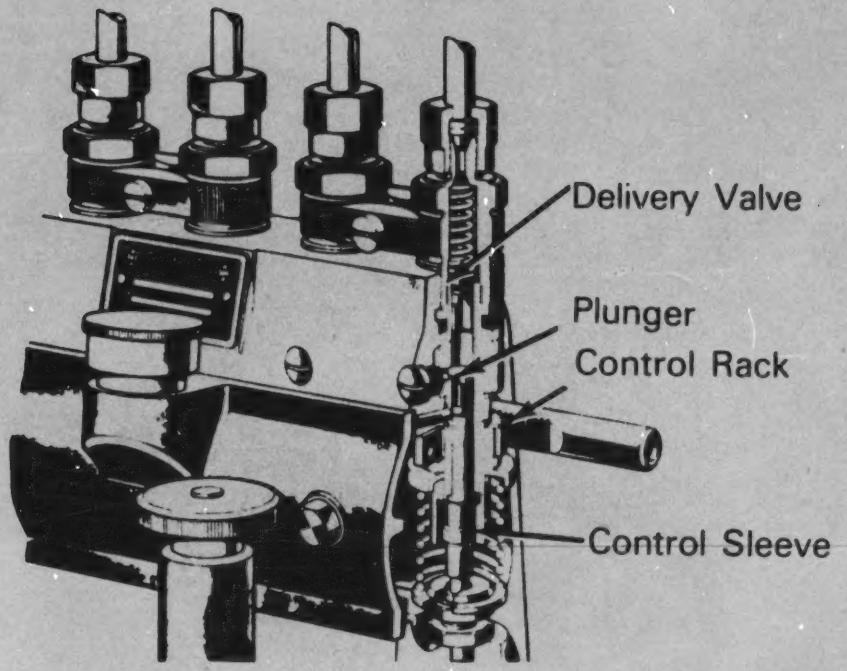
Injection Pump Operation



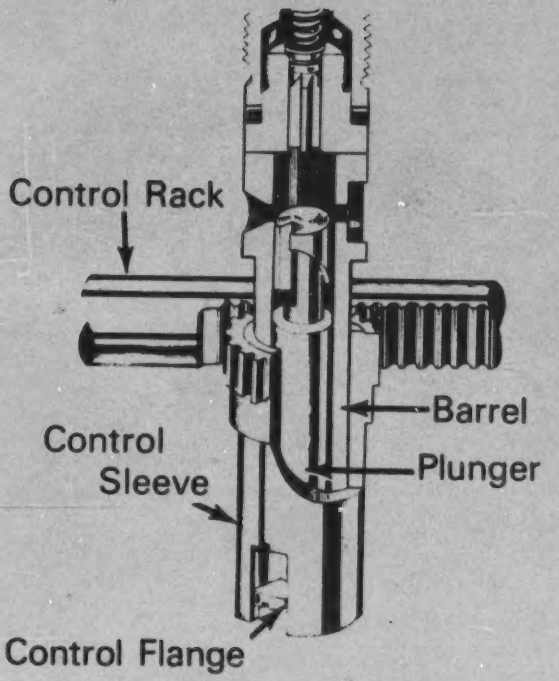
Parts And Design Of Pumping Element



Control Rack And Sleeve

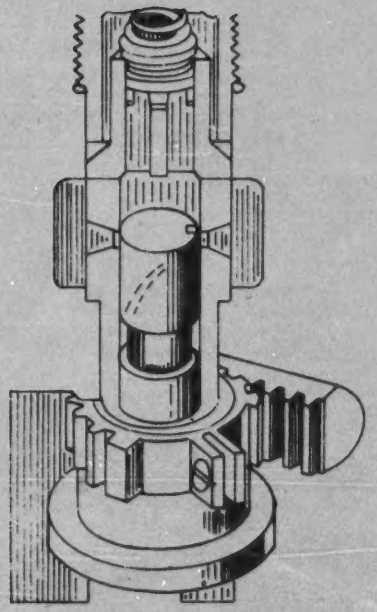


Control Rack, Sleeve, and Delivery Valve



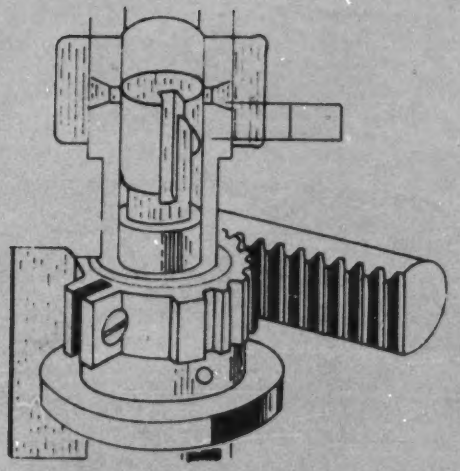
Plunger Rotation Mechanism.
(American Bosch AMBAC Industries, Inc.)

Plunger Positions At Fuel Delivery

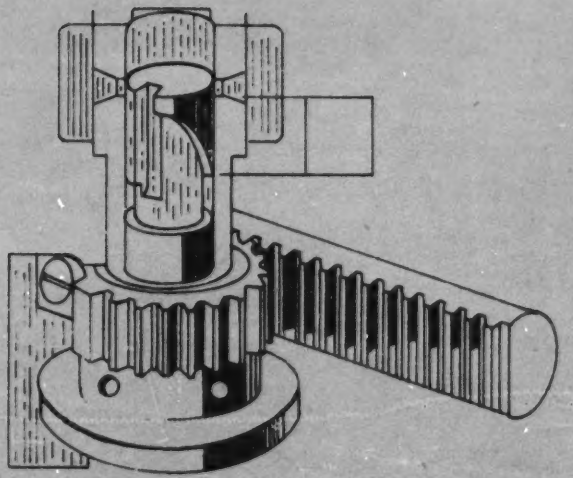


No Fuel Delivery

711



Partial Fuel Delivery



Maximum Fuel Delivery

712

IN-LINE INJECTION PUMP
UNIT III

JOB SHEET #1--BENCH TEST IN-LINE INJECTION PUMP

(NOTE: The job sheet detailed here is general and requires the use of a test stand manual, pump specifications sheet, and the appropriate engine service manual.)

I. Tools and materials

A. Basic hand tool set

B. Test standard adapters

C. Test stand manual

D. Pump tools

(NOTE: In addition to basic hand tool set you may need a special tool set for the pump you are working on.)

E. Pump

F. Pump specification sheet and appropriate service manual

G. Lint free shop towels

H. Safety glasses

II. Procedure

A. Thoroughly clean pump exterior

B. Rotate pump camshaft two or three complete turns

(NOTE: If camshaft turns abnormally hard or will not turn, pump must be disassembled and repaired. See appropriate technical manual.)

C. Prepare test stand as required

D. Attach pump

(NOTE: Use appropriate adapters and procedures as specified in test stand manual, pump specifications sheet, and service manual.)

E. Check and adjust pump timing or port closure using pump specification sheet and appropriate service manual

(NOTE: Port closure is defined as the position of the plunger as it moves upward, at the instant the barrel port is just completely covered and fuel flow stops. With the control rack locked in the 12mm position, the plunger will be correctly rotated so that port closure will take place on the extreme top edge of plunger, instead of on the retard notch.)

JOB SHEET #1

1. Check pump timing--low pressure method

(NOTE: The low pressure timing method must be used if the test stand is not equipped with a high pressure pump. This method requires the removal of the delivery valve, stop and spring, and delivery valve holder for each of the plungers. If the test stand is equipped with a high pressure pump, the high pressure timing method is preferred to the low timing method, since the delivery valve and related parts do not have to be removed.)

(CAUTION: To prevent possible injury, do not connect hose to high pressure outlet on test stand when using this method. The high pressure pump supplies test fuel at approximately 700 psi pressure. The low pressure installation is intended for the use of test fuel subjected to 70 psi or less.)

2. Check pump timing--Low pressure method

(NOTE: The high pressure outlet enables the injection pump to be checked for port closure without having to remove the delivery valve, spring and spacer, and delivery valve holder. On some of the other model test stands, a mobile high pressure unit is available to perform high pressure timing of the injection pump. Use the following procedure to prepare pump for high pressure timing.)

F. Operate pump to bring temperature and pressure up to manufacturer's specification

(NOTE: Until now, tests and adjustments were made without driving the injection pump. To finish adjusting the governor (and to make other adjustments as well), it will be necessary to drive the injection pump. Therefore, to prevent pump damage, be certain that pump is filled with oil to the proper level.)

G. Adjust pumping elements, rack position and speed

(NOTE: This is done to balance delivery. Check pump specification sheet and appropriate service manual for exact amounts.)

H. Adjust governor

(NOTE: Specification sheet, and service manual settings should be followed exactly. Variations from prescribed settings can cause engine to run improperly.)

JOB SHEET #1

I. Replace all covers

J. Run pump and check for leaks

K. Remove pump from stand

L. Seal pump

(NOTE: Use seal wires, cap all pump openings, and repaint the pump.)

IN-LINE INJECTION PUMP
UNIT III

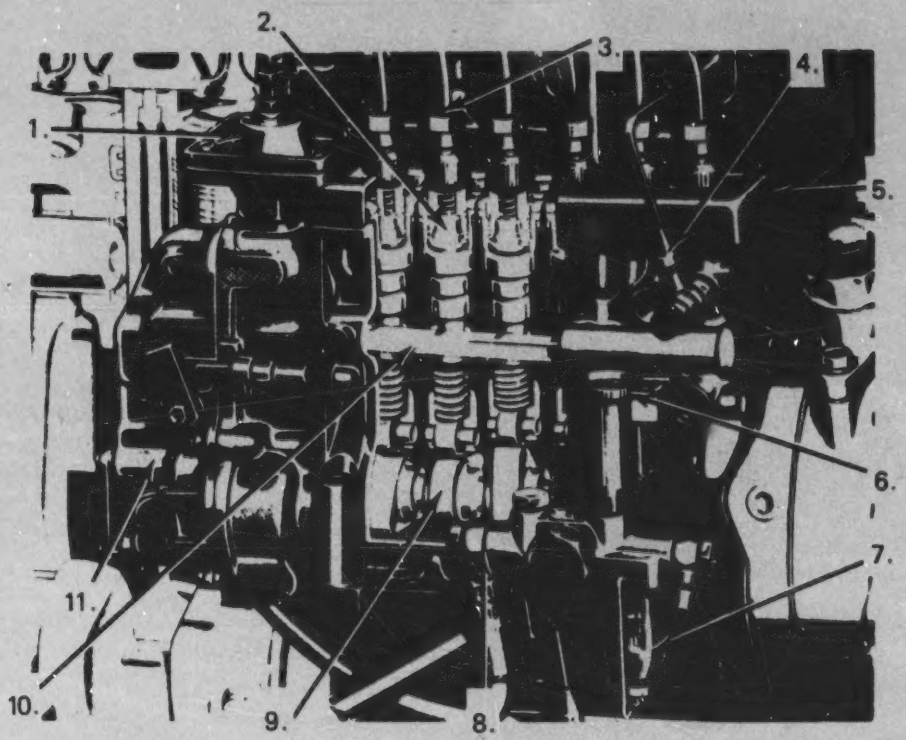
NAME_____

TEST

1. Match the terms on the right to the correct definitions.

_____a. Sends fuel at low pressure through filters to the injection pump	1. Annular groove
_____b. Machined recess forming a ring on pumping plunger	2. Helix
_____c. Located at right angles to the plane of the supporting surface	3. Gallery
_____d. Spiraled, machined recess on pumping plunger	4. In-line injection pump
_____e. Long, narrow fuel or oil passage	5. Transfer pump (supply pump)
_____f. Device which limits fuel supply to engine, preventing excess smoke	6. Vertical slot
_____g. Uses an individual pump for each cylinder with pumps mounted in-line	7. Aneroid

2. Match the main parts of the in-line pump to its name by placing the correct numbers in the appropriate blanks.



_____a. Control rack

_____b. Governor

_____c. Sediment bowl

_____d. Aneroid

_____e. Fuel transfer pump

_____f. Individual pumping element

_____g. Hand primer

_____h. Injection line

_____i. Pump housing

_____j. Leak-off line

_____k. Camshaft

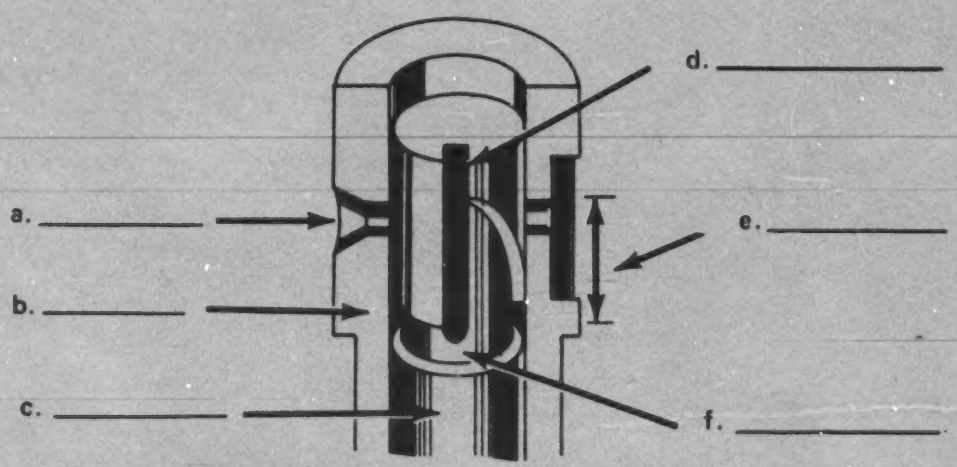
3. Trace the fuel flow from supply tank to delivery.

4. State the purpose of the hand primer.

5. Explain the purpose of the fuel transfer pump.

6. Discuss the operation of the injection pump.

7. Identify parts and design features of the pumping element.



8. Explain the operation of the control rack and sleeve.

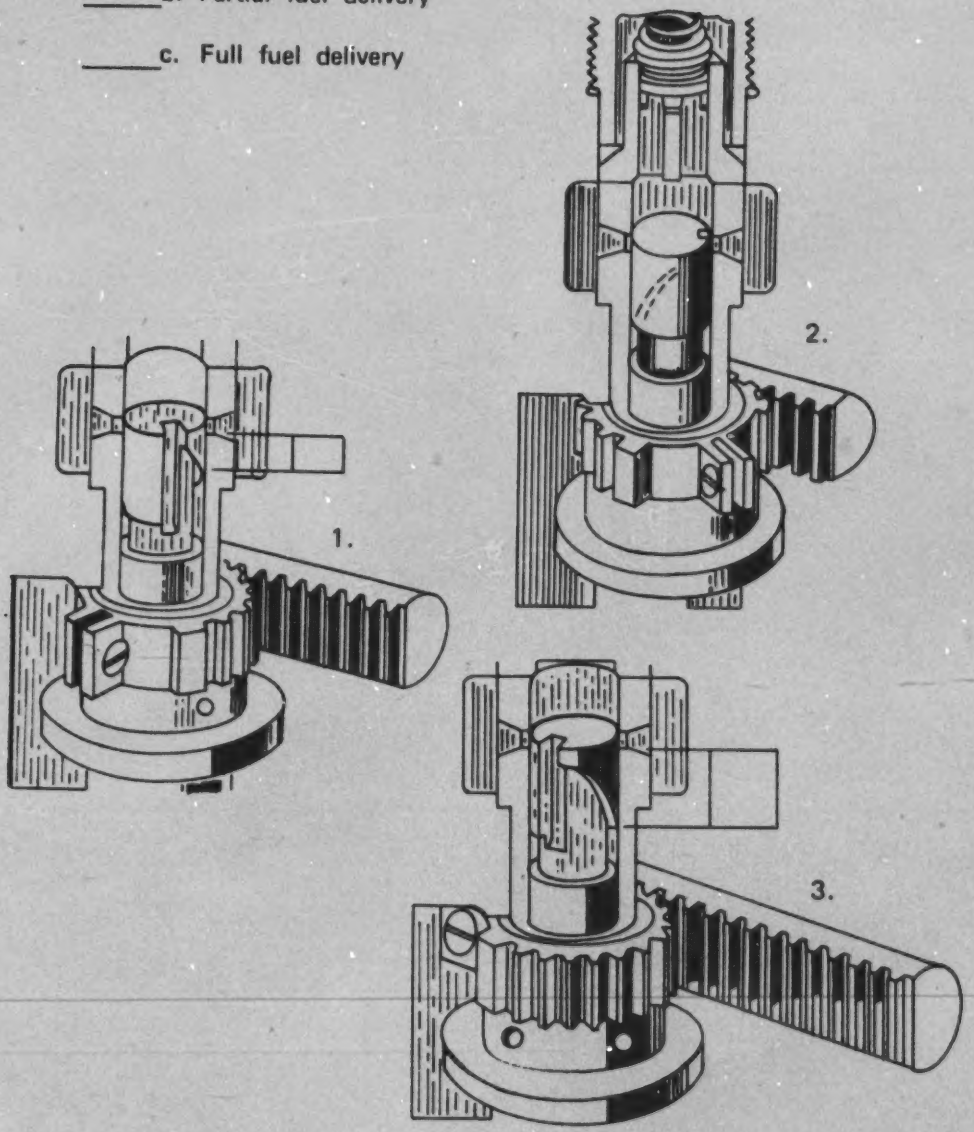
9. State the purpose of the delivery valve.

10. Identify the plunger and rack positions.

_____a. No fuel delivery

_____b. Partial fuel delivery

_____c. Full fuel delivery



11. Demonstrate the ability to bench test an in-line injection pump.

(NOTE: If this activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

IN-LINE INJECTION PUMP
UNIT III

ANSWERS TO TEST

1. a. 5
   b. 1
   c. 6
   d. 2
   e. 3
   f. 7
   g. 4

2. a. 10
   b. 11
   c. 7
   d. 1
   e. 8
   f. 2
   g. 6
   h. 3
   i. 5
   j. 4
   k. 9

3. a. Fuel is drawn from supply tank through primary filter by fuel transfer pump

   b. Transfer pump forces fuel under low pressure through secondary filter and through final stage filter to each injection pumping element

   c. Pumping element meters fuel at high pressure to each injection nozzle for delivery to combustion chamber

4. Hand primer on fuel transfer pump can be operated by hand to pump fuel when bleeding the system

5. Explanation should include:

   a. Draws fuel from supply tank through primary filter

   b. Assures fuel supply to injection pumping elements

6. Discussion should include:

   a. Plunger type pump has engine driven camshaft rotating at half engine speed

   b. Roller cam followers, riding on cam lobes, operate the plungers to supply high pressure fuel through delivery valves to injection nozzles

7. a. Spill ports

   b. Barrel

   c. Plunger

   d. Vertical slot

   e. Helix

   f. Annular groove

8. Explanation should include:

   a. Governor moves rack to regulate speed of engine

   b. The sleeve, rotated by the control rack, is fitted over the barrel and connects to the vanes on the plunger

   c. Plunger rotation opens or closes the helix which meters the quantity of fuel for delivery to cylinder

9. The delivery valve creates a sudden pressure drop in the delivery line causing the injector nozzle valve to close instantly

10. a. 2

    b. 1

    c. 3

11. Performance skill evaluated to the satisfaction of the instructor

UNIT INJECTOR
UNIT IV

UNIT OBJECTIVE

After completion of this unit, the student should be able to list the functions of the unit injector and match the parts of the unit injector to part names. The student should also be able to discuss fuel flow and explain how fuel is metered. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with the unit injector to the correct definitions.
2. Match the parts of the unit injector to the correct part names.
3. List functions of the unit injector.
4. Discuss fuel flow through the unit injector fuel system.
5. Explain how fuel is metered during the injection stroke.
6. Demonstrate the ability to:
   a. Remove unit injector from engine.
   b. Disassemble unit injecter.
   c. Assemble unit injector.
   d. Test unit injector.
   e. Install unit injector.

UNIT INJECTOR
UNIT IV

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined in the job sheets.

G. Demonstrate lapping and cleaning procedures.

H. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete job sheets.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Unit Injector
2. TM 2--Parts of Unit Injector (Needle Valve)
3. TM 3--Fuel Flow Through Unit Injector (Crown Valve)
4. TM 4--Plunger Positions

D. Job sheets

1. Job Sheet #1--Remove Unit Injector from Engine
2. Job Sheet #2--Disassemble Unit Injector
3. Job Sheet #3--Assemble Unit Injector
4. Job Sheet #4--Test Unit Injector
5. Job Sheet #5--Install Unit Injector

E. Test

F. Answers to test

II. Reference--*Service Manual, Detroit Diesel Engines.* Detroit, Michigan: Detroit Diesel Allison, 1975.

UNIT INJECTOR
UNIT IV

INFORMATION SHEET

I. Terms and definitions

A. Spray valve--Serves as a nozzel to atomize fuel sprayed into combustion chamber

B. Helix--Spiraled recess machined into plunger

C. Port--Drilled passage in bushing

D. Control rack and gear--Rack and pinion gear arrangement on unit injector

E. Bushing--Serves as a barrel for the plunger on the unit injector

F. Unit injector--Injection pump, injector, and spray valve form a single unit (Transparency 1)

(NOTE: One unit is provided for each cylinder.)

II. Parts of unit injectors (Transparency 2)

A. Follower

B. Follower spring

C. Stop pin

D. Filter cap

E. Plunger

F. Gasket

G. Injector body

H. Filter

I. Gear

J. Gear retainer

K. Dowel

L. Control rack

INFORMATION SHEET

M. Seal

N. Bushing

O. Spill deflecter

P. Lower port

Q. Upper port

R. Check valve

S. Check valve cage

T. Valve spring

U. Spring cage

V. Spring seat

W. Needle valve

X. Body unit

Y. Spray tip

Z. Identification tag

III. Functions of the unit injector

A. Creates a high fuel pressure

(NOTE: This is needed for efficient injection.)

B. Meters required amount of fuel

C. Atomizes the fuel

D. Times injection

E. Injects fuel

(NOTE: Fuel and air are mixed in the combustion chamber.)

IV. Fuel flow through the unit injector fuel system (Transparency 3)

A. Enters injector through a filter cap and filter

B. Passes through drilled passages and ports into supply chamber

(NOTE: The supply chamber is that area between the plunger bushing and the spill deflector, in addition to that area under the injector plunger within the bushing.)

INFORMATION SHEET

C. Pump pressure forces fuel through small orifices in spray tip

D. Atomized into combustion chamber

V. Metering fuel (Transparency 4)

(NOTE: Changing the position of the helices by rotating the plunger increases or decreases the amount of fuel injected into the cylinder.)

A. No injection

1. Control rack out

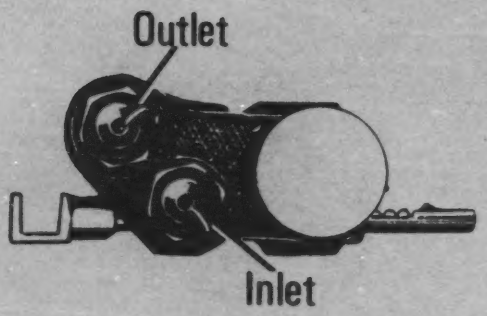
2. Upper port is not closed by helix

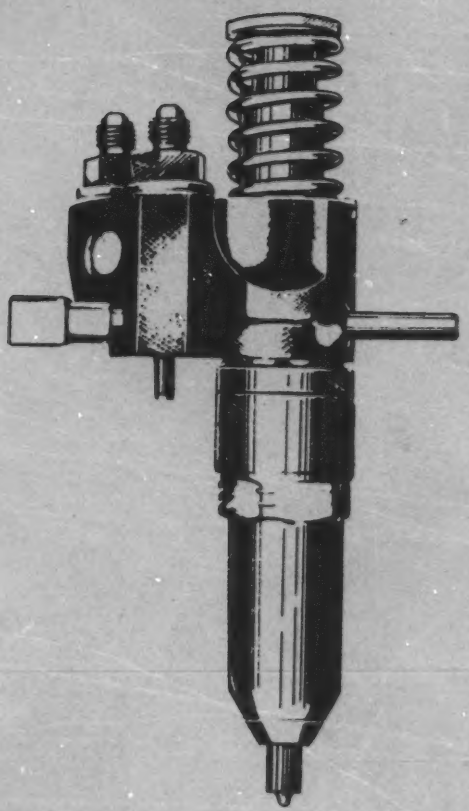
B. Full injection

1. Control rack in

2. Upper port is closed and lower port is closed by helix

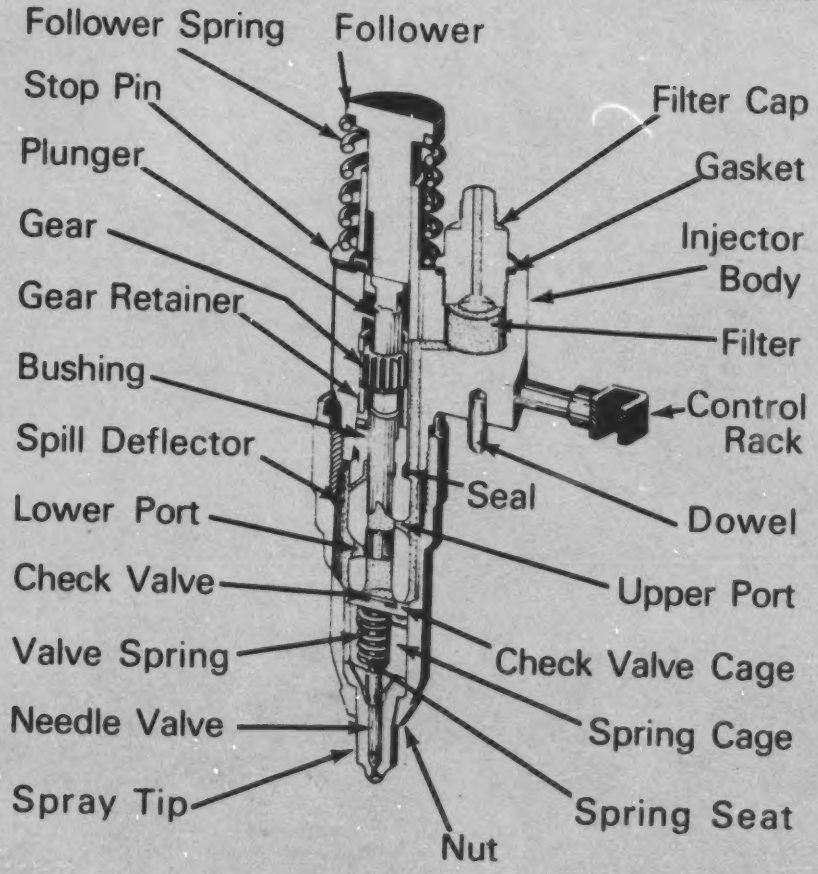
Unit Injector

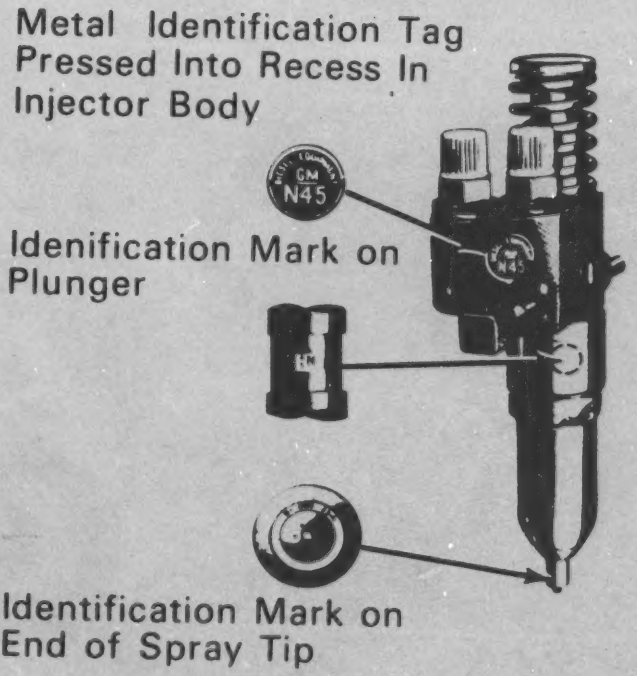




Parts Of Unit Injector

Needle Valve

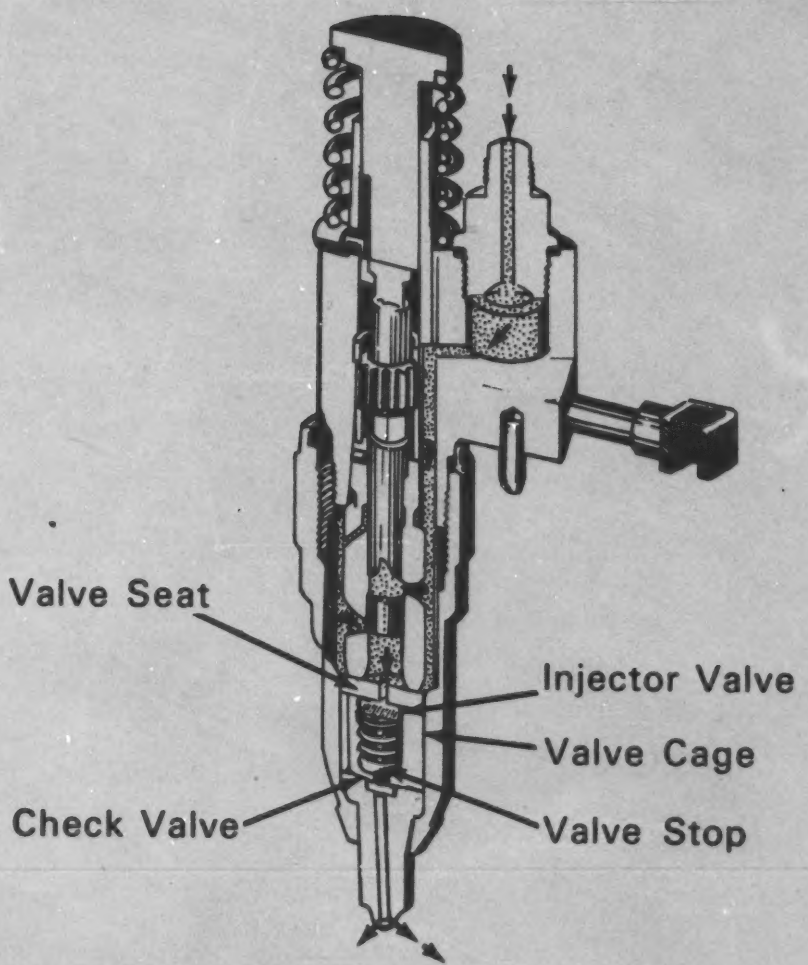



Metal Identification Tag Pressed Into Recess In Injector Body
Idenification Mark on Plunger
Identification Mark on End of Spray Tip

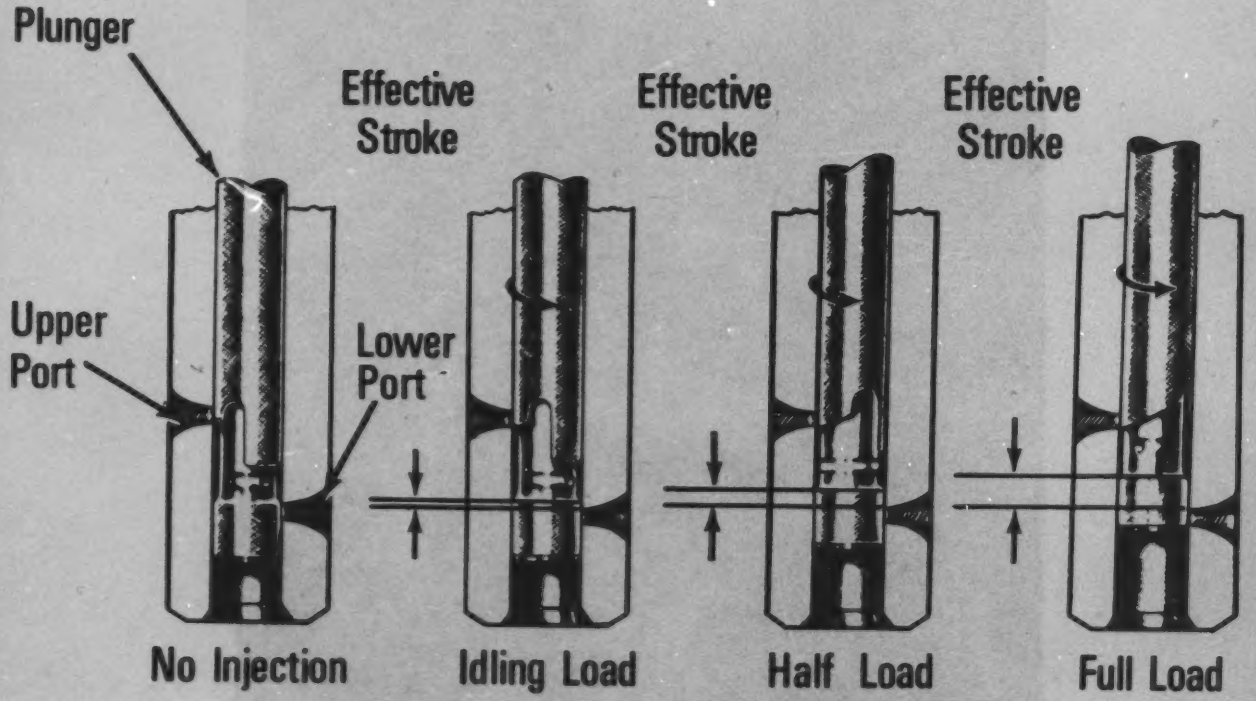
(Note: Fuel injector shown has needle valve installed. See identification tag on injector body to determine type injector valve in use. Refer to service manual for correct procedure when reworking crown valve, needle valve, high valve, or conversion kit service.)

Fuel Flow Through Unit Injector

Crown Valve



Plunger Positions



Various plunger positions from no-load to full-load of unit injector.

UNIT INJECTOR
UNIT IV

JOB SHEET #1--REMOVE UNIT INJECTOR FROM ENGINE

I. Tools and materials

A. Needle valve fuel injector

(NOTE: For specific installations and models get detailed service from the manufacturer's service manual.)

B. Hand tool set

C. Pry bar

D. Shop towel (lint free)

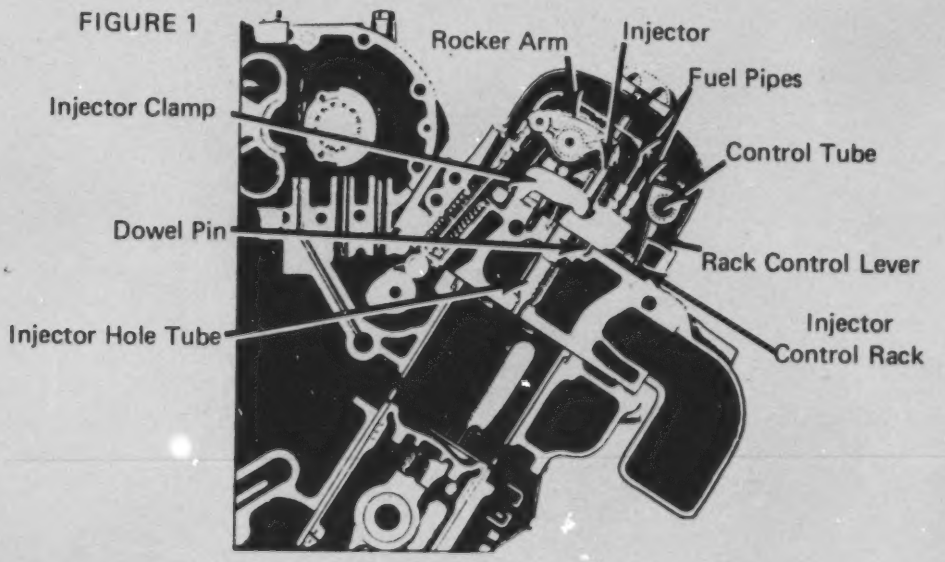
E. Safety glasses

II. Procedure

A. Remove the valve rocker cover

B. Remove the fuel pipes from both the injector and the fuel connectors (Figure 1)

FIGURE 1



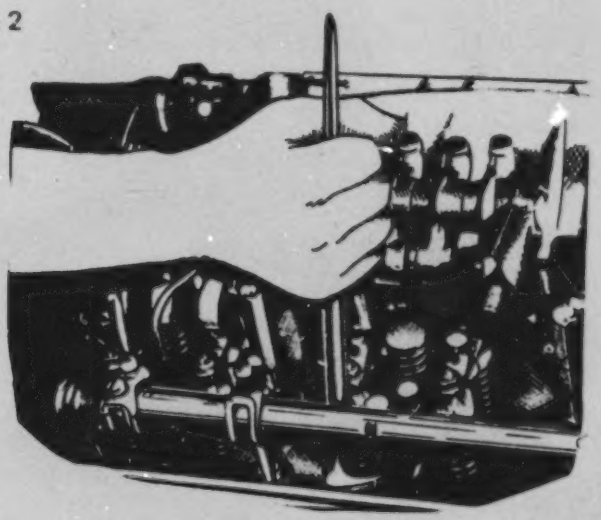
(NOTE: Immediately after removal of the fuel pipes from an injector, cover the filter caps with shipping caps to prevent dirt from entering the injector. Also protect the fuel pipes and fuel connectors from entry of dirt or foreign material.)

JOB SHEET #1

C. Rotate the engine to bring the outer ends of the push rods of the injector and valve rocker arms in line horizontally

D. Remove the two rocker shaft bracket bolts and swing the rocker arms away from the injector and valves (Figure 2)

FIGURE 2



E. Remove the injector clamp bolt, special washer, and clamp

F. Loosen the inner and outer adjusting screws on the injector rack control lever and slide the lever away from the injector

G. Lift the injector from its seat in the cylinder head (Figure 2)

H. Cover the injector hole in the cylinder head to keep foreign material out

I. Clean the exterior of the injector with clean fuel oil and dry it with compressed air

UNIT INJECTOR
UNIT IV

JOB SHEET #2–DISASSEMBLE UNIT INJECTOR

I. Tools and materials

A. Needle valve fuel injector

(NOTE: For specific installations and models get detailed service and specifications from the manufacturer's service manual. Normally in industry unit injectors are pretested before disassembly.)

B. Injector nut socket wrench

C. Injector spray tip driver

D. Injector vise and rack freeness tester

E. Hand tool set

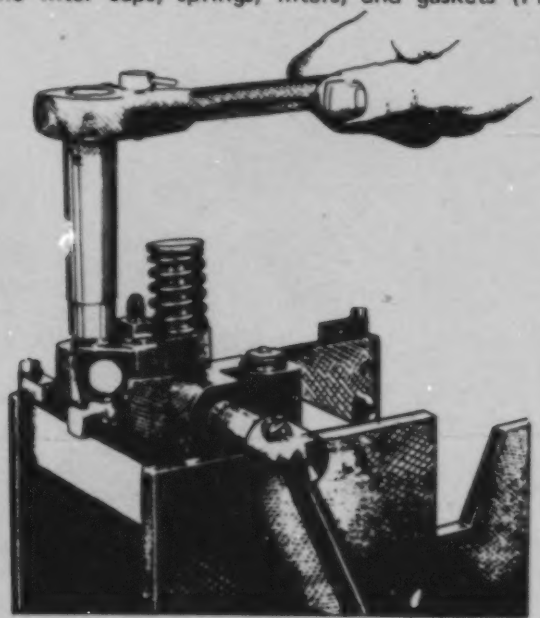
F. Shop towels (lint free)

G. Safety glasses

II. Procedure

A. Support the injector upright in injector vise and rack freeness tester and remove the filter caps, springs, filters, and gaskets (Figure 1)

FIGURE 1

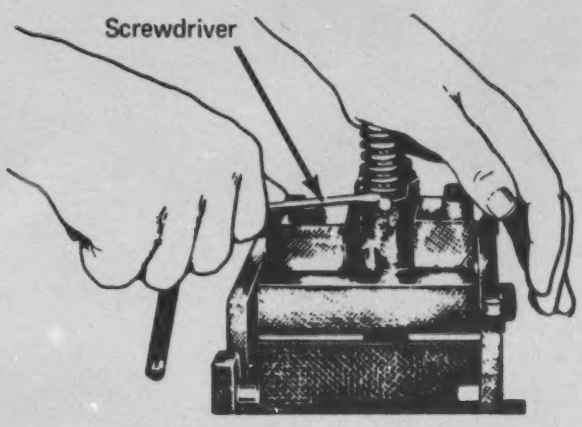


(NOTE: Whenever a fuel injector is disassembled, discard the filters and gaskets and replace with new filters and gaskets.)

JOB SHEET #2

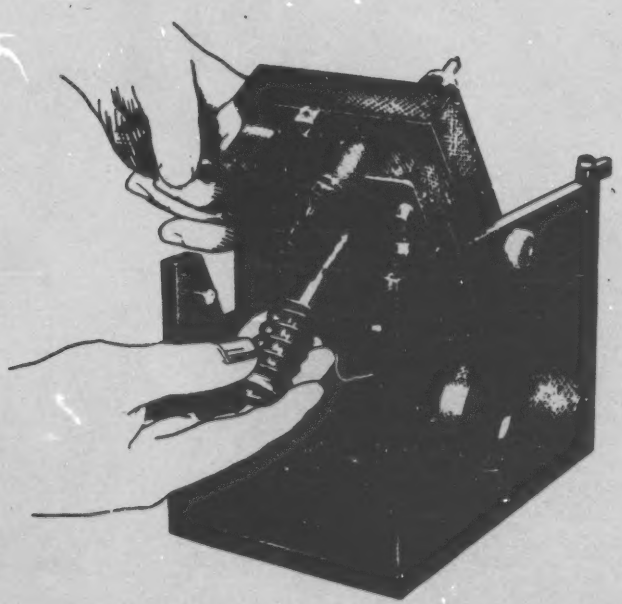
B. Compress the follower spring and raise the spring above the stop pin with a screw driver and withdraw the pin and allow the spring to rise gradually (Figure 2)

FIGURE 2



C. Remove the plunger follower, plunger, and spring as an assembly (Figure 3)

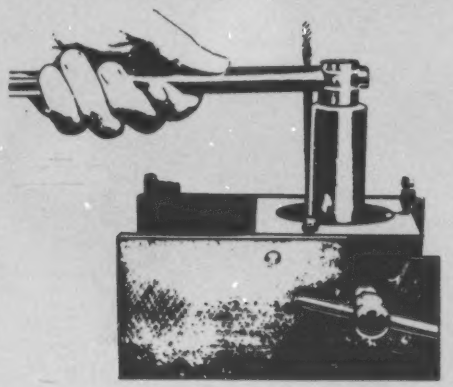
FIGURE 3



JOB SHEET #2

D. Invert the fixture and, using injector nut socket wrench, loosen the nut on the injector body (Figure 4)

FIGURE 4

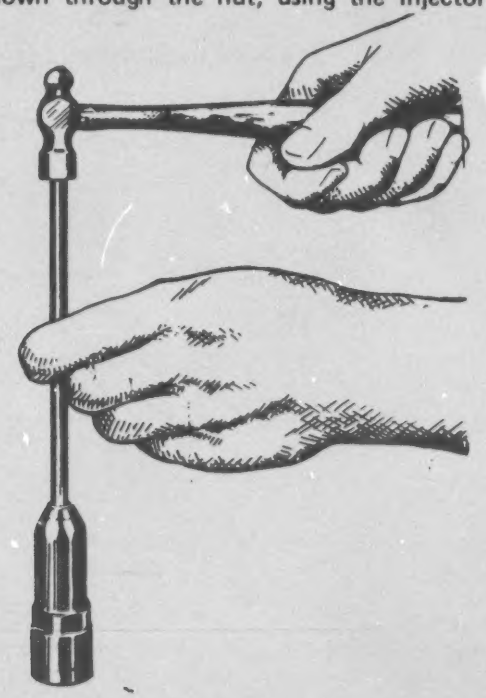


E. Lift the injector nut straight up, being careful not to dislodge the spray tip and valve parts

F. Remove the spray tip and valve parts from the bushing and place them in a clean receptacle until ready for assembly

(NOTE: When an injector has been in use for some time, the spray tip, even though clean on the outside, may not be pushed readily from the nut with the fingers. In this event, support the nut on a wood block and drive the tip down through the nut, using the injector spray tip driver. See Figure 5.)

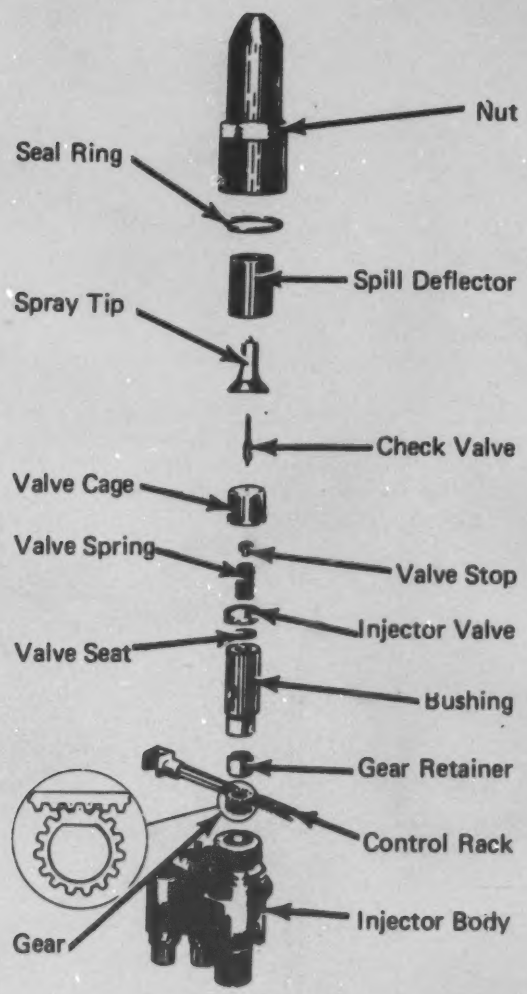
FIGURE 5



JOB SHEET #2

G. Remove the spill deflector and the seal ring from the injector nut (Figure 6)

FIGURE 6



H. Remove the plunger bushing, gear retainer, and gear from the injector body

I. Withdraw the injector control rack from the injector body

UNIT INJECTOR
UNIT IV

JOB SHEET #3--ASSEMBLE UNIT INJECTOR

I. Tools and materials

A. Needle valve fuel injector

(NOTE: For specific installations and models get detailed service and specifications from the manufacturer's service manual.)

B. Injector vise and rack freeness tester

C. Injector nut socket wrench

D. 9/16" deep well socket

E. Torque wrench

F. Hand tool set

G. Shop towels (lint free)

H. Safety glasses

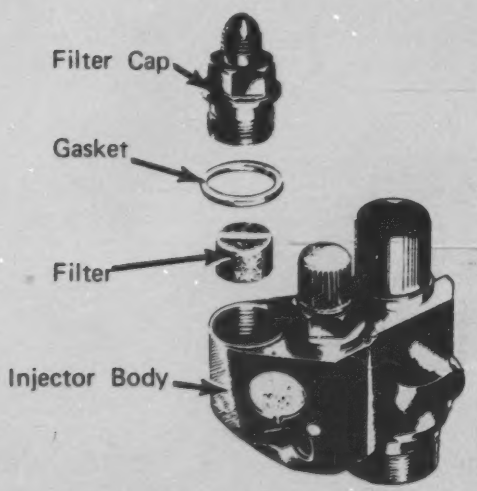
II. Procedure

A. Assemble injector filters

(NOTE: Use an extremely clean bench to work on and to place parts when assembling an injector. Also be sure all injector parts, both new and used, are clean. Flush parts in fuel oil or calibrating oil during assembly.)

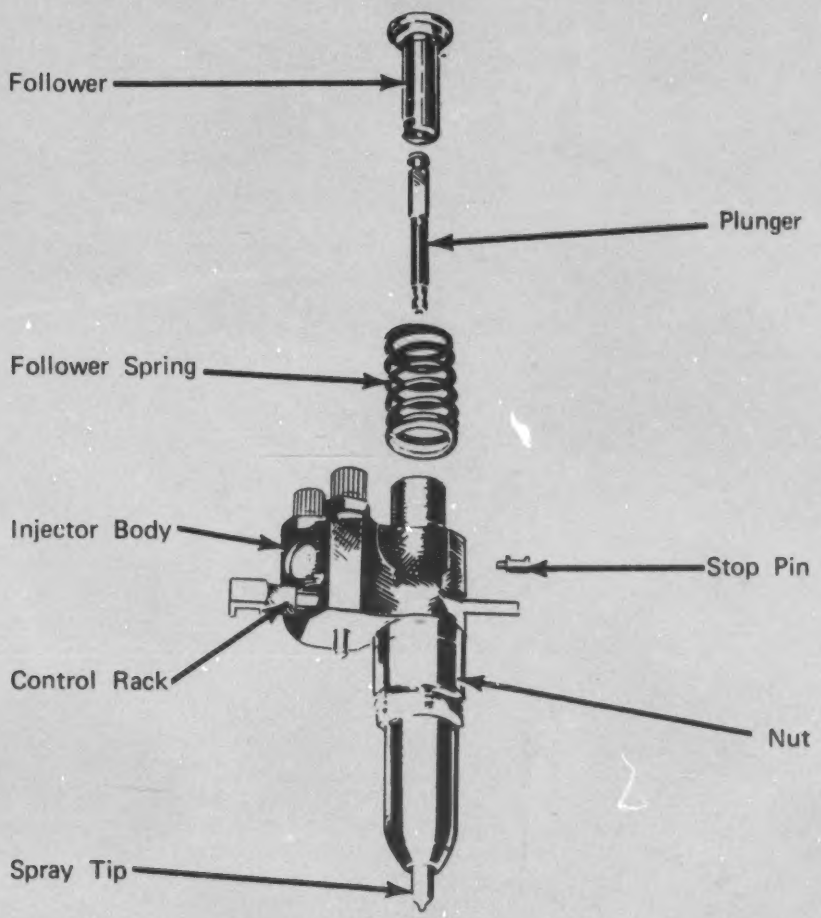
1. Study relative position of injector parts (Figures 1 and 2)

FIGURE 1



JOB SHEET #3

FIGURE 2



2. While holding the injector body right side up, place a new filter (slot in the filter up or toward the filter cap) in each of the fuel cavities in the top of the injector body (Figure 1)

3. Place a spring on top of each filter (if an early design filter cap is used) and a new gasket on each filter cap

4. Lubricate the threads and install the filter caps

5. Use a 9/16" deep socket wrench and tighten the filter caps to specified torque

6. Purge the filters after installation by directing compressed air or fuel through the filter caps

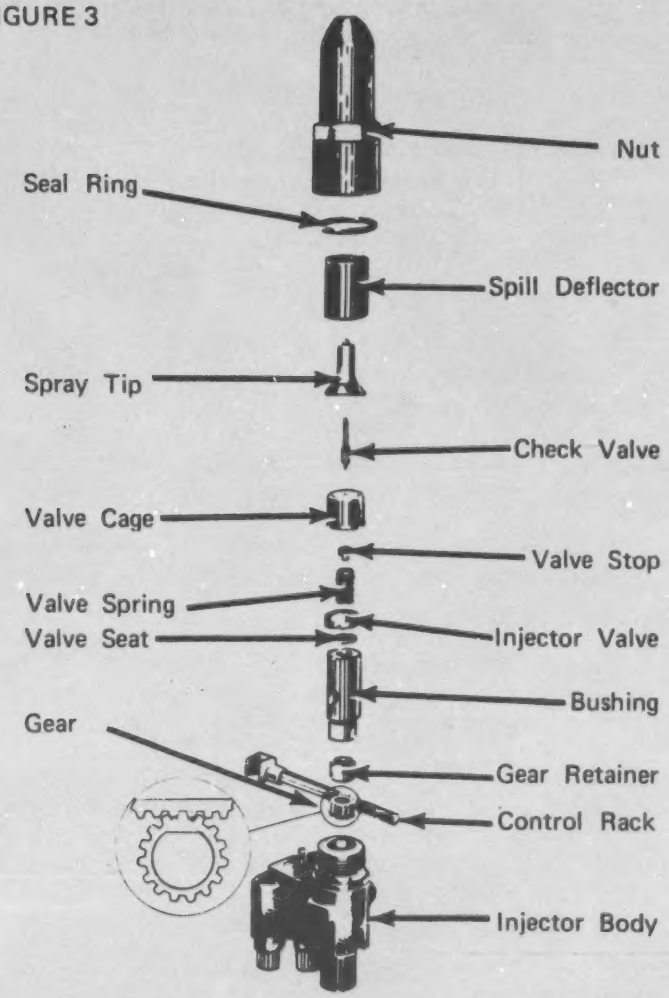
7. Install clean shipping caps on the filter caps to prevent dirt from entering the injector

JOB SHEET #3

B. Assemble rack and gear

(NOTE: Observe the drill spot marks (timing marks) on the control rack and gear. See Figure 3.)

FIGURE 3



JOB SHEET #3

1. Hold the injector body, bottom end up, and slide the rack through the hole in the body

2. Look into the bore for the rack teeth, then move the rack until you can see the drill marks and hold the rack in this position

3. Place the gear in the injector body so that the marked tooth is engaged between the two marked teeth on the rack

4. Place the gear retainer on top of the gear

5. Align the locating pin in the bushing with the slot in the injector body, then slide the end of the bushing into place

C. Assemble injector valve and related parts

(NOTE: Make sure the injector valve and related parts have been lapped and cleaned. See Figure 3.)

1. Support the injector body, bottom end up, in the injector vise and freeness tester

2. Place a new seal ring on the shoulder of the body, then slide the spill deflector over the barrel of the bushing

3. Place the valve seat on the end of the bushing and insert the stem of the valve in one end of the valve spring and the valve stop in the other end

4. Lower the valve cage over this assembly so that the valve stop seats in the cage and place the valve cage assembly on the valve seat

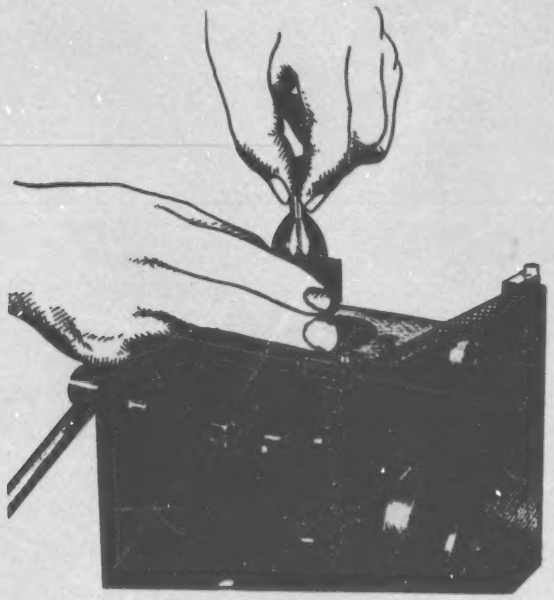
5. Locate the check valve centrally on the cage and place the spray tip over the check valve and against the valve cage

JOB SHEET #3

6. Lubricate the threads in the injector nut and carefully thread the nut on the injector body by hand

(NOTE: Rotate the spray tip between your thumb and first finger while threading the nut on the injector body. See Figure 4.)

FIGURE 4



7. Tighten the nut as tight as possible by hand

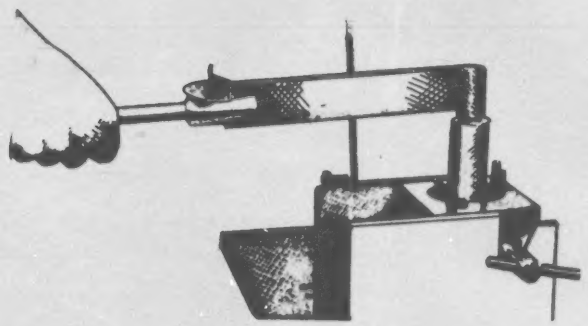
(NOTE: At this point there should be sufficient force on the spray tip to make it impossible to turn with your fingers.)

JOB SHEET #3

8. Use injector nut socket wrench and a torque wrench to tighten the injector nut to specified torque (Figure 5)

(NOTE: Do not exceed the specified torque. Otherwise, the nut may be stretched and result in improper sealing of the lapped surfaces in a subsequent injector overhaul. Avoid cross threading the nut during installation.)

FIGURE 5



D. Assemble plunger and follower

1. Slide the head of the plunger into the follower (Figure 2)

2. Invert the injector in the assembly fixture (filter cap end up) and push the rack all the way in; then place the follower spring on the injector body

3. Place the stop pin on the injector body so that the follower spring rests on the narrow flange of the stop pin

4. Align the slot in the follower with the stop pin hole in the injector body

5. Align the flat side of the plunger with the slot in the follower

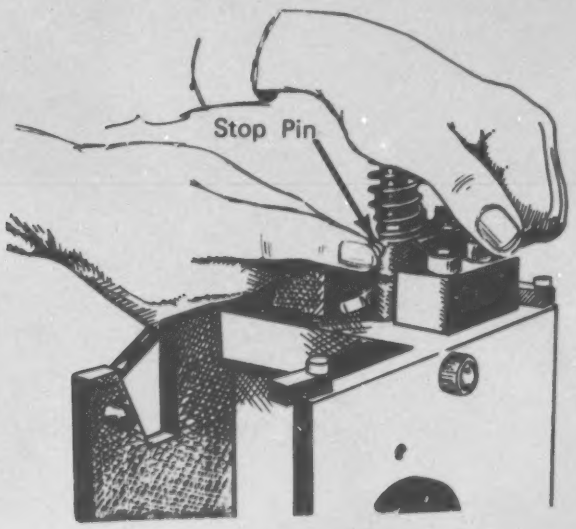
6. Insert the free end of the plunger in the injector body

JOB SHEET #3

7. Press down on the follower and at the same time press the stop pin into position (Figure 6)

(NOTE: When in place, the spring will hold the stop pin in position.)

FIGURE 6



UNIT INJECTOR
UNIT IV

JOB SHEET #4--TEST UNIT INJECTOR

I. Tools and materials

A. Needle valve fuel injector

(NOTE: For specific installations and models get detailed service and specifications from the manufacturer's service manual.)

B. Hand tool set

C. Injector vise and rack freeness tester

D. Injector tester

E. Comparator injector tester or

F. Appropriate calibrator injector tester (See Figures 5 and 6)

G. Shop towel (lint free)

H. Safety glasses

II. Procedure

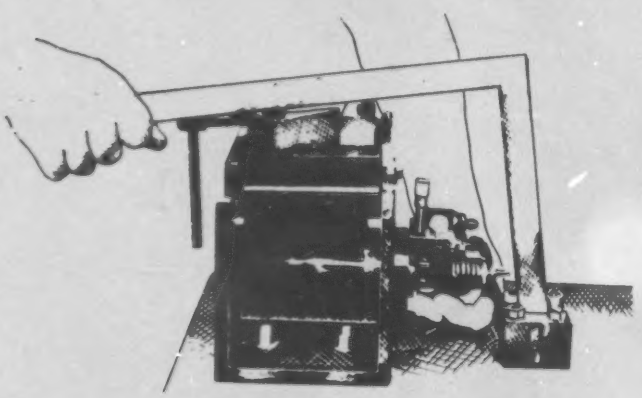
(NOTE: Identify each injector and record the pressure drop and fuel output as indicated by the following tests.)

A. Test injector control rack and plunger movement

1. Place the injector in the injector fixture and rack freeness tester

2. Place the handle on top of the injector follower (Figure 1)

FIGURE 1



(NOTE: If necessary, adjust the contact screw in the handle to ensure the contact screw is at the center of the follower when the follower spring is compressed.)

3. With the injector control rack held in the no-fuel position, push the handle down and depress the follower to the bottom of its stroke

4. Very slowly release the pressure on the handle while moving the control rack up and down until the follower reaches the top of its travel (See Figure 1)

(NOTE: If the rack does not fall freely, loosen the injector nut, turn the tip, then retighten the nut. Loosen and retighten the nut a couple of times if necessary. Generally this will free the rack. Then, if the rack isn't free, change the injector nut. In some cases it may be necessary to disassemble the injector to eliminate the cause of the misaligned parts.)

B. Test injector valve opening pressure

(NOTE: The purpose of the valve opening pressure test is to determine the pressure at which the valve opens and injection begins.)

1. Place the injector in the tester with the dowel on the underside of the injector located in the proper slot of the adaptor plate

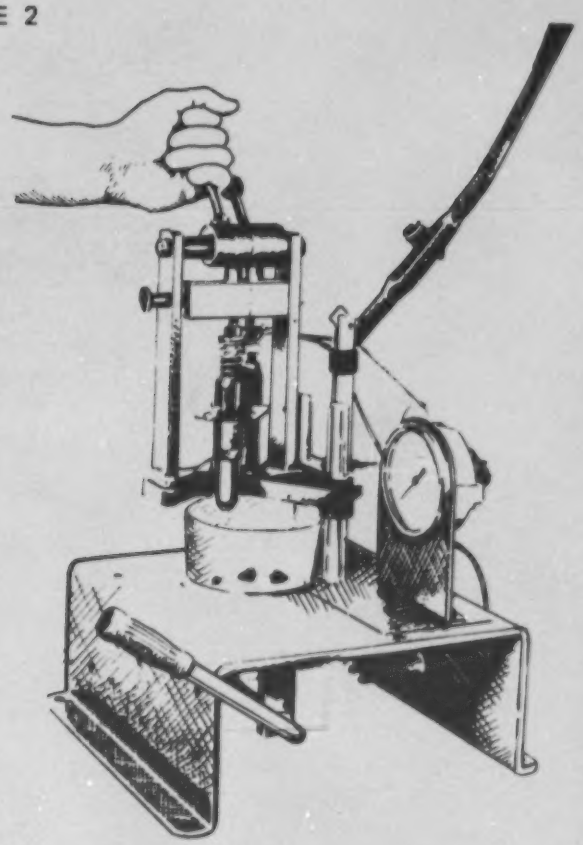
2. Position the injector handle support to the proper height (Figure 2)

(NOTE: When testing an injector just removed from an engine, the flow of fuel through the injector on the tester should be the same as in the engine. Connections on the test head of the tester may be changed to obtain the correct direction of flow.)

JOB SHEET #4

(CAUTION: Always place the injector in the proper position in relation to the spray deflector before it is tested to prevent the fuel spray from penetrating the skin. Fuel oil which enters the blood stream can cause a serious infection.)

FIGURE 2

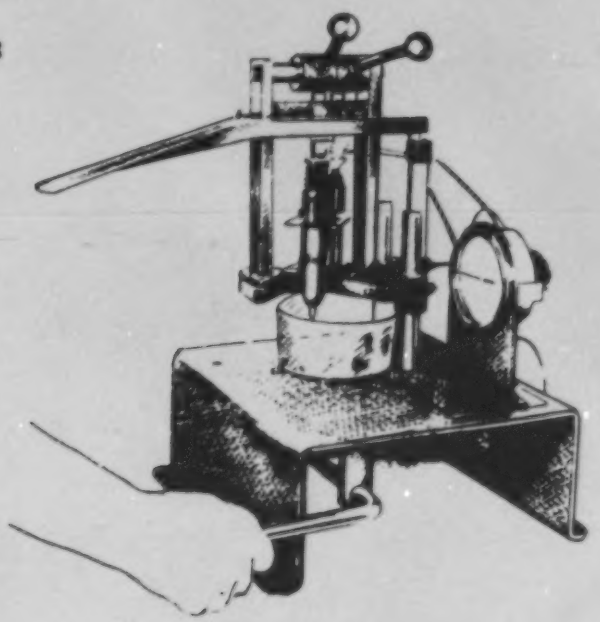


3. Close the inlet clamp and operate the pump handle until all of the air is purged from the injector tester and the injector, then close the outlet clamp

JOB SHEET #4

4. With the injector rack in the full-fuel position, pump the handle of the injector tester with smooth, even strokes and record the injector valve opening pressure indicated when the injector sprays fuel (Figure 3)

FIGURE 3



(NOTE: The specified valve opening pressure is 450 to 850 psi. If the pressure is not within the above range, refer to manufacturer's troubleshooting chart.)

C. Injector valve holding pressure test

(NOTE: The injector valve holding pressure test will determine whether the various lapped surfaces in the injector are sealing properly.)

1. Operate the pump handle to bring the pressure up to a point just below the injector valve opening pressure (approximately 450 psi)

2. Close the fuel shut-off valve and note the pressure drop

(NOTE: The time for a pressure drop from 450 psi to 250 psi should not be less than 40 seconds. If the pressure drop is less than 40 seconds, follow procedures a through c below.)

JOB SHEET #4

a. Thoroughly dry the injector with compressed air

b. Open the tester fuel valve and operate the pump handle to maintain the test pressure

c. Correct malfunctions as appropriate

1) A leak around the spray tip or seal ring usually is caused by a loose injector nut, a damaged seal ring, or hardened surface on the injector nut or spray tip

2) A leak at the filter cap indicates a loose filter cap or damaged filter cap gasket

3) A "dribble" at the spray tip orifices indicates a leaking valve aassembly due to a damaged surface or dirt; leakage at the tip will cause pre-ignition in the engine

(NOTE: A drop or two of fuel at the spray tip is only an indication of the fuel trapped in the spray tip at the beginning of the test and is not detrimental as long as the pressure drop specified is not less than 40 seconds.)

D. Perform injector high pressure test

(NOTE: This test is performed to discover any fuel leaks at the injector filter cap gaskets, body plugs and nut seal ring which did not appear during the valve holding pressure test. The high pressure test also indicates whether or not the plunger and bushing clearance is satisfactory.)

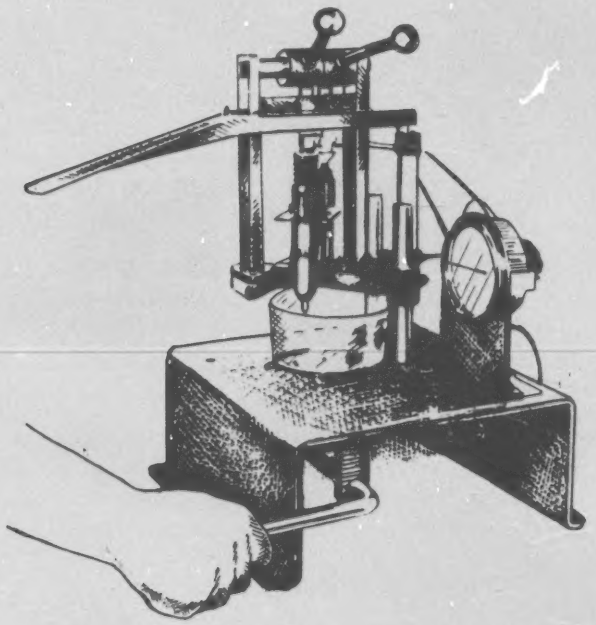
1. Thoroughly dry the injector with compressed air

2. Check the fuel connections for leaks; if leaks have occurred, tighten the connections, dry the injector and recheck

JOB SHEET #4

3. With the injector rack in the full-fuel position and the injector tester handle locked in position by means of the handle lock, operate the pump handle to build up and maintain the pressure (Figure 4)

FIGURE 4



4. Use the adjusting screw in the injector tester handle to depress the injector plunger just far enough to close both ports in the injector bushing

(NOTE: The point at which both ports are closed may be easily ascertained by the fact that the injector spray will decrease appreciably and a rise in pressure will occur. At this time, the condition of the plunger and bushing may be established. If there is excessive clearance between the plunger and bushing, pressure beyond the normal valve opening pressure cannot be obtained. Replacement of the plunger and bushing assembly is then required.)

5. Pump up the injector tester and maintain a pressure of 1600 to 2000 psi by actuating the pump handle, then inspect for leaks at the injector filter cap gaskets, body plugs, and injector nut seal ring

JOB SHEET #4

(NOTE: If any of these conditions exist, refer to manufacturer's troubleshooting chart. It is normal for fuel to seep out around the rack due to high pressure fuel being applied to a normally low pressure area in the injector assembly. However, fuel droplets at the rack indicate excessive leakage.)

(CAUTION: Do not permit the pressure in the injector tester to equal or exceed the capacity of the pressure gauge.)

E. Spray pattern test

1. Open the fuel shut-off valve, place the injector rack in the full-fuel position and operate the injector several times in succession by operating the tester handle at approximately 40 strokes per minute

2. Observe the spray pattern to see that all spray orifices are open and injecting evenly

(NOTE: The beginning and ending of injection should be sharp and the fuel injected should be finely atomized. See Figure 4.)

3. If all of the spray tip orifices are not open and injecting evenly, clean the orifices in the spray tip

(CAUTION: To prevent damage to the pressure gauge, do not exceed 100 psi during this test.)

F. Test fuel output

(NOTE: The injector fuel output test can be performed in either the comparator J 7041 or the calibrator J 22410. See Figures 5 and 6.)

(CAUTION: When injectors are removed from an engine for fuel output testing and, if satisfactory, reinstalled without disassembly, extreme care should be taken to avoid reversing the fuel flow. When the fuel flow is reversed, dirt trapped by the filter is back-flushed into the injector components.)

JOB SHEET #4

(NOTE: Before removing an injector from the engine, observe the direction of the fuel flow. To avoid reversing the fuel flow when checking injector fuel output, use the appropriate adaptor. The position of the fuel flow pipes on the comparator depends on the adaptor being used and the direction of fuel flow through the injector. See Figure 5. The position of the braided fuel inlet tube and the plastic fuel outlet tube on the calibrator depends on the adaptor being used and the direction of fuel flow through the injector. See Figure 6.)

FIGURE 5

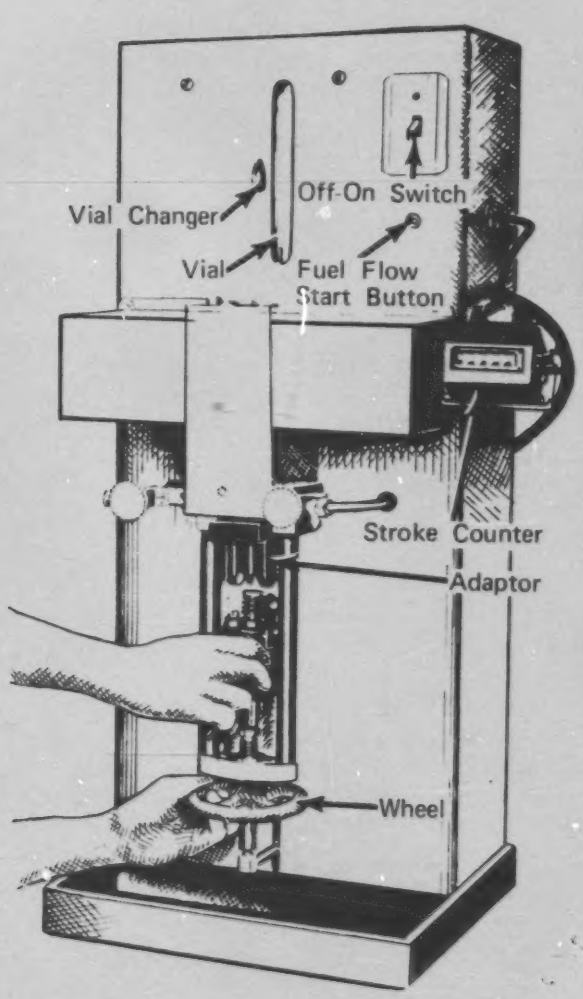
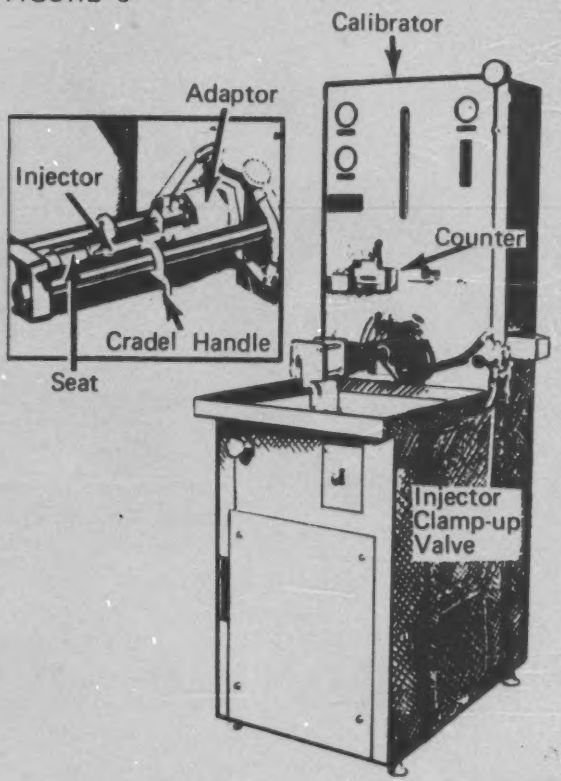


FIGURE 6



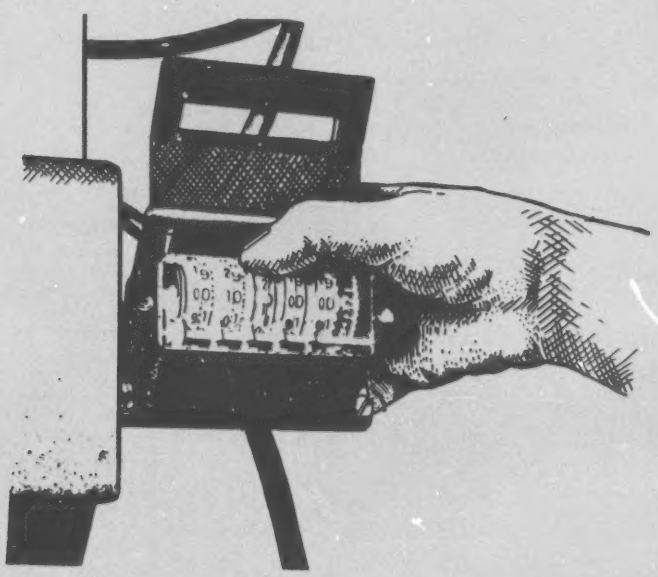
JOB SHEET #4

1. Check fuel output using appropriate comparator (Figure 5)

   a. Place the injector in the comparator and tighten the hand wheel to clamp the injector and adaptor in position

      (NOTE: Make sure the counter on the comparator is preset to 1000 strokes. If, for any reason, this setting has been altered, raise the cover and reset the counter to 1000 strokes by pulling the selector wheel to be changed to the right and rotating it to its proper setting. Then release the wheel and close the cover. Refer to the comparator instruction booklet for further information. See Figure 7.)

FIGURE 7



      (NOTE: When installing a low clamp body injector in the comparator, position the injector in the adaptor at approximately a 45° angle, rather than straight into the adaptor, then bring it into a vertical position and secure it in place.)

   b. Pull the injector rack out to the no-fuel position

   c. Start the comparator by turning on the switch

   d. After the comparator has started, push the injector rack in the full-fuel position

JOB SHEET #4

e. Let the injector run for approximately 30 seconds to purge the air that may be in the system

f. After 30 seconds, press the fuel flow start button

(NOTE: This will start the flow of fuel into the vial. The comparator will automatically stop the flow of fuel after 1000 strokes.)

g. After the fuel stops flowing into the vial, pull the injector rack out to the no-fuel position

h. Turn the comparator off and reset the counter

i. Observe the reading on the vial and refer to figure 8 to determine if the injector fuel output falls within its specified limits

(NOTE: If the quantity of fuel in the vial does not fall within the specified limits, refer to manufacturer's troubleshooting chart for cause and remedy.)

FIGURE 8

Injector	Calibrator J 22410		Comparator J 7041	
	Min.	Max.	Min.	Max.
5S8	50	54	9	15
6S8	53	57	10	16
S55	55	59	14	20
S60	59	63	18	24
S65	64	68	24	30
S70	71	75	30	36
S80	80	84	38	44
S90	87	92	46	52

2. Check fuel output using appropriate calibrator (Figure 6)

a. Place the cam shift index wheel and fuel flow lever in their respective positions

b. Turn on the test fuel oil heater switch and preheat the test oil to 95° to 105°F

c. Place the proper injector adaptor between the tie rods and engage it with the fuel block locating pin

JOB SHEET #4

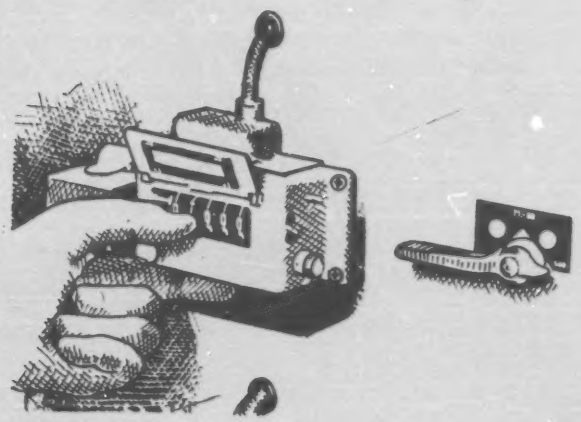
d. Slide the adaptor forward and up against the fuel block face

e. Place the injector seat into the permanent seat (cradle handle in vertical position)

f. Clamp the injector into position by operating the air valve

(NOTE: Make sure the counter on the calibrator is preset at 1000 strokes. See Figure 9. If for any reason this setting has been altered, reset the counter to 1000 strokes by twisting the cover release button to the left and hold the reset lever in the full up position while setting the numbered wheels. Close the cover. Refer to the calibrator instruction booklet for further information.)

FIGURE 9



g. Pull the injector rack out to the no-fuel position

h. Turn on the main power control circuit switch

i. Start the calibrator by turning on the motor starter switch

(NOTE: The low oil pressure warning buzzer will sound briefly until the lubricating oil reaches the proper pressure.)

j. After the calibrator has started, set the injector rack into the full-fuel position

(NOTE: Allow the injector to operate for approximately 30 seconds to purge the air that may be in the system.)

JOB SHEET #4

k. After the air is purged, press the fuel flow start button (red)

(NOTE: This will start the flow of fuel into the vial. The fuel flow to the vial will automatically stop after 1000 strokes.)

l. Shut the calibrator off (the calibrator will stop in less time at full fuel)

m. Observe the vial reading and refer to Figure 8 to determine whether the injector fuel output falls within the specified limits

(NOTE: If the quantity of fuel in the vial does not fall within the specified limits, refer to manufacturer's troubleshooting chart for the cause and remedy.)

(NOTE: The comparator or the calibrator may be used to check and select a set of injectors which will inject the same amount of fuel in each cylinder at a given throttle setting, thus resulting in a smooth running, well balanced engine. An injector which passes all of the above tests may be put back into service. However, an injector which fails to pass one or more of the tests must be rebuilt and checked on the comparator or the calibrator. Any injector which is disassembled and rebuilt must be tested again before being placed in service.)

UNIT INJECTOR
UNIT IV

JOB SHEET #5--INSTALL UNIT INJECTOR

I. Tools and materials

A. Needle valve fuel injector

(NOTE: For specific installations and models get detailed service and specifications from the manufacturer's service manual.)

B. Hand tool set

C. Injector tube bevel reamer

D. Fuel pipe socket

E. Torque wrench

F. Grease

G. Shop towels (lint free)

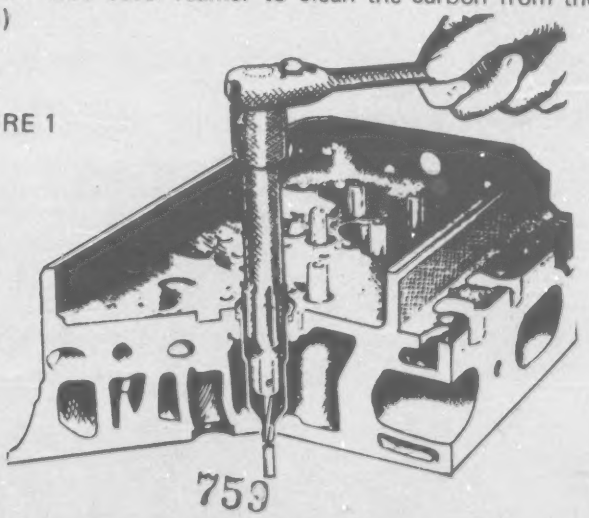
H. Safety glasses

II. Procedure

(NOTE: Before installing an injector in an engine, remove the carbon deposits from the beveled seat of the injector tube in the cylinder head. This will assure correct alignment of the injector and prevent any undue stresses from being exerted against the spray tip.)

A. Use injector tube bevel reamer to clean the carbon from the injector tube (Figure 1)

FIGURE 1



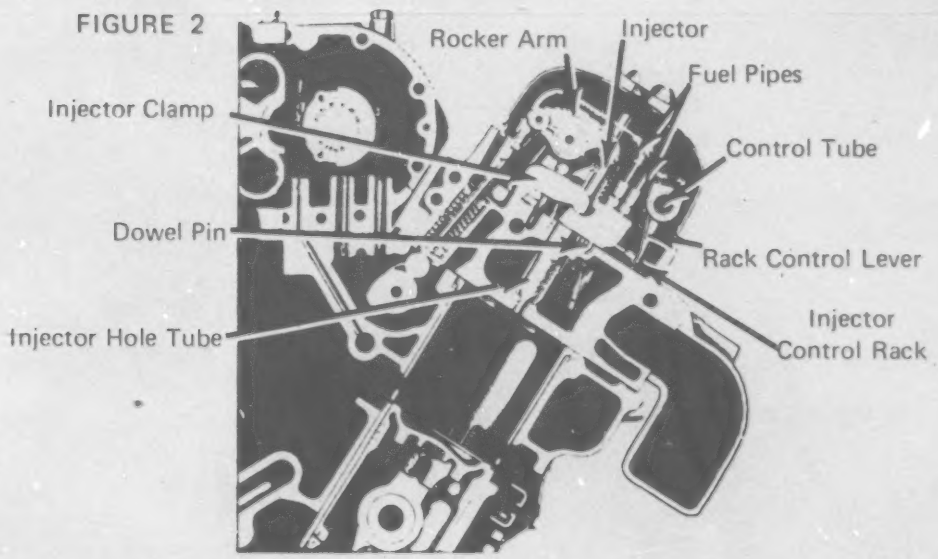
JOB SHEET #5

(CAUTION: Exercise care to remove ONLY the carbon so that the proper clearance between the injector body and the cylinder head is maintained. Pack the flutes of the reamer with grease to retain the carbon removed from the tube.)

(NOTE: Be sure the fuel injector is filled with fuel oil. If necessary, add clean fuel oil at the inlet filter cap until it runs out of the outlet filter cap.)

B. Insert the injector into the injector tube with the dowel in the injector body registering with the locating hole in the cylinder head (Figure 2)

FIGURE 2



C. Slide the rack control lever over so that it registers with the injector rack

D. Install the injector clamp, special washer (with curved side toward injector clamp) and bolt and tighten the bolt to specified torque, making sure that the clamp does not interfere with the injector follower spring or the exhaust valve springs

(NOTE: Check the injector control rack for free movement. Excess torque can cause the control rack to stick or bind.)

JOB SHEET #5

E. Move the rocker arm assembly into position and secure the rocker arm brackets to the cylinder head by tightening the bolts to the torque specified in service manual

(CAUTION: On four valve cylinder heads, there is a possibility of damaging the exhaust valves if the exhaust valve bridges are not resting on the ends of the exhaust valves when tightening the rocker shaft bracket bolts. Therefore, note the position of the exhaust valve bridges before, during, and after tightening the rocker shaft bolts.)

F. Remove the shipping caps, then install the fuel pipes and connect them to the injector and the fuel connectors, using fuel pipe socket to tighten the connections to specified torque

(NOTE: A specified fuel pipe socket may be needed. Refer to appropriate service manual.)

(CAUTION: Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared end of the fuel line and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings.)

G. Refer to service manual for final adjustments and tune-up procedures

UNIT INJECTOR
UNIT IV

NAME _____

TEST

1. Match the terms on the right to the correct definitions.

_____a. Serves as a nozzle to atomize fuel sprayed into combustion chamber

_____b. Spiraled recess machined into plunger

_____c. Drilled passage in bushing

_____d. Rack and pinion gear arrangement on unit injector

_____e. Serves as a barrel for the plunger on the unit injector

_____f. Injection pump, injector, and spray valve form a single unit

1. Bushing
2. Control rack and gear
3. Spray valve
4. Unit Injector
5. Helix
6. Port

2. Match the parts of the unit injector on the right to the correct part names.

_____a. Follower

_____b. Plunger

_____c. Gear

_____d. Valve spring

_____e. Filter

_____f. Spray tip

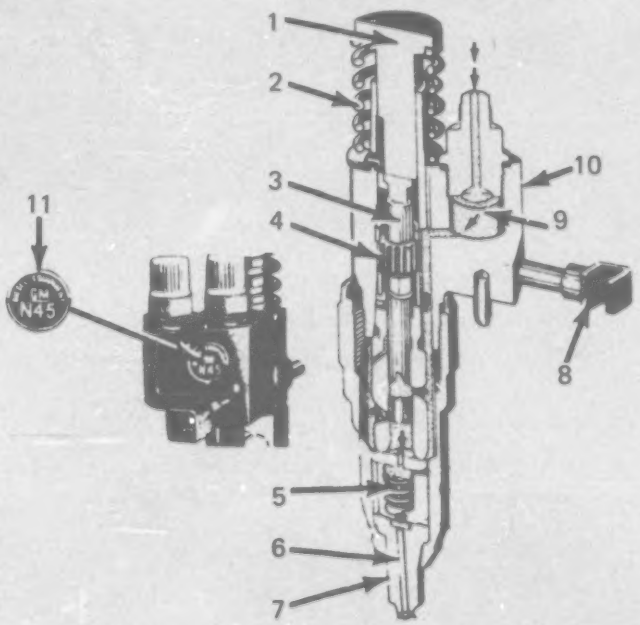
_____g. Control rack

_____h. Needle valve

_____i. Injector body

_____j. Follower spring

_____k. Identification tag



3. List three functions of the unit injector.

   a.

   b.

   c.

4. Discuss fuel flow through the unit injector fuel system.

5. Explain how fuel is metered during the injection stroke.

   a. No injection

      1)

      2)

   b. Full injection

      1)

      2)

6. Demonstrate the ability to:

   a. Remove unit injector from engine.

   b. Disassemble unit injector.

   c. Assemble unit injector.

   d. Test unit injector.

   e. Install unit injector.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

UNIT INJECTOR
UNIT IV

ANSWERS TO TEST

1. a. 3
   b. 5
   c. 6
   d. 2
   e. 1
   f. 4
2. a. 1
   b. 3
   c. 4
   d. 5
   e. 9
   f. 7
   g. 8
   h. 6
   i. 10
   j. 2
   k. 11
3. Any three of the following:
   a. Creates a high fuel pressure
   b. Meters required amount of fuel
   c. Atomizes the fuel
   d. Times injection
   e. Injects fuel
4. Discussion should include:
   a. Enters injector through a filter cap and filter
   b. Passes through drilled passages and ports into supply chamber
   c. Pump pressure forces fuel through small orifices in spray tip
   d. Atomized into combustion chamber
5. a. No injection
      1) Control rack out
      2) Upper port is not closed by helix
   b. Full injection
      1) Control rack in
      2) Upper port is closed and lower port is closed by helix
6. Performance skills evaluated to the satisfaction of the instructor

PT FUEL SYSTEMS
UNIT V

UNIT OBJECTIVE

After completion of this unit, the student should be able to name the main parts of a pressure time fuel injection system and discuss its operation. The student should also be able to install a PT type pump, and remove and install PT injectors. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with the PT fuel system to the correct definitions.
2. Name the three main parts of the PT fuel system.
3. Match the main units of the PT pump assembly to their functions.
4. Discuss the operation of the PT injection system.
5. State the function of the pulsation damper.
6. Explain the operation of the mechanical governor.
7. Name two types of PT injectors.
8. Match the operation steps of the PT injectors to their description.
9. Demonstrate the ability to:
    a. Remove and install flange type PT injectors.
    b. Remove and install PT (type B, C, and D) injectors.
    c. Adjust injector plunger and valves using torque method.
    d. Install PT-R fuel pump and adjust high and low engine idle.
    e. Test and adjust PT-G fuel pump.

PT FUEL SYSTEMS
UNIT V

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined in the job sheets.

G. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete job sheets.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Main Parts of PT Fuel System
2. TM 2--PT Pump Assembly
3. TM 3--PT Pump Assembly (Continued)
4. TM 4--Types of Injectors
5. TM 5--Operation of Injectors

D. Job sheets

1. Job Sheet #1--Remove and Install Flange Type PT Injectors
2. Job Sheet #2--Remove and Install PT (Type B, C, and D) Injectors
3. Job Sheet #3--Adjust Injector Plunger and Valves Using Torque Method
4. Job Sheet #4--Install PT-R Fuel Pump and Adjust High and Low Engine Idle
5. Job Sheet #5--Test and Adjust PT-G Fuel Pump

E. Test

F. Answers to test

II. References:

A. Toboldt, Bill. *Diesel: Fundamentals, Service, Repair.* South Holland, Illinois: Goodheart-Willcox Company, 1973.

B. Kates, Edgar J., and Luck, William E. *Diesel and High Compression Gas Engines.* Chicago: American Technical Society, 1974.

C. *Service Bulletin No. 3379011-01: Injector Plunger and Valve Adjustments.* Columbus, Indiana: Cummins Engine Co., December, 1975.

D. *Service Bulletin No. 3379101-00: PT Fuel Pump Calibration.* Columbus, Indiana: Cummins Engine Co., December, 1975.

E. *Service Bulletin No. 3379071-02: Injectors, All Types.* Columbus, Indiana: Cummins Engine Co., December, 1975.

F. *Service Bulletin No. 983725: Calibration of PT-G pumps.* Columbus, Indiana: Cummins Engine Co., 1975.

G. *Service Bulletin No. 983535: Fuel Pump PT Rebuilding.* Columbus, Indiana: Cummins Engine Co., 1975.

PT FUEL SYSTEMS
UNIT V

INFORMATION SHEET

I. Terms and definitions

A. PT system--Pressure time system based on the principle that the volume of liquid flow is proportionate to the fluid pressure, the time allowed to flow, and the size of the passage through which the liquid flows

B. PT type G--PT fuel pump which is governor controlled

C. PT type R--PT fuel pump which is pressure regulated

D. Purge--To get rid of trapped fuel

E. Rated speed--Engine rpm's under full load

F. Meter--To supply in a measured amount

G. High idle or maximum no-load speed--Engine rpm's with no-load and throttle fully open

II. Main parts of PT fuel system (Transparency 1)

A. Fuel pump

B. Supply lines, drain lines, and passages

C. Injectors

III. Functions of units of PT pump assembly (Transparencies 2 and 3)

A. Gear pump--Draws fuel from supply tank forcing it through the pump filter screen into the pressure regulator valve

B. Pressure regulator--Limits the pressure of the fuel to the injectors

C. Throttle--Provides a manual control of fuel flow to the injector under all conditions in the operating range

D. Governor assembly--Controls the flow of fuel from idle to maximum governor speed

IV. Operation of PT injection system

A. Gear type fuel pump delivers fuel through a restricting throttle to the governor

B. From the governor, the fuel goes to a manifold which feeds cam-operated injectors in the cylinder head

INFORMATION SHEET

C. Injector raises pressure to produce a good spray and times the start of injection

V. Function of pulsation damper--The damper contains a steel diaphragm which absorbs pulsations and smooths fuel flow through system (Transparency 2)

(NOTE: The pulsation damper, mounted on gear pump, performs the same function on both type G and type R fuel pumps.)

VI. Operation of mechanical governor (Transparency 3)

A. Between idle and maximum speed, fuel flows through the governor to the injector in accordance with engine requirements as controlled by the throttle

B. When engine reaches governed speed, the governor weights move the governor plungers so fuel passage to the injectors is shut off

(NOTE: At the same time another passage opens and dumps the fuel back into the main pump body. The engine speed is controlled and limited regardless of the position of the throttle.)

C. Fuel leaving the governor flows through the shut down valve, inlet supply lines, and onto the injectors

VII. Types of PT injectors (Transparency 4)

A. Flanged

B. Cylindrical

VIII. Operation steps of PT injectors (Transparency 5)

A. Metering

1. Fuel enters the injector at fuel inlet

(NOTE: Pressure is determined by throttle and/or governor.)

2. Metering orifice controls quantity of fuel that enters the injector cup

(NOTE: Pressure is determined by the fuel pump and the time interval during which the hole supplying fuel is uncovered by the injector plunger.)

INFORMATION SHEET

B. Injection

1. Downward plunger movement cuts off fuel entry into injector cup

2. Continued downward movement forces fuel from injector cup through the orifice into combustion chamber

   (NOTE: High pressures allow for almost complete burning of fuel spray.)

3. While plunger is down fuel passes through upper hole around undercut in plunger through return passages to the fuel tank

C. Purging

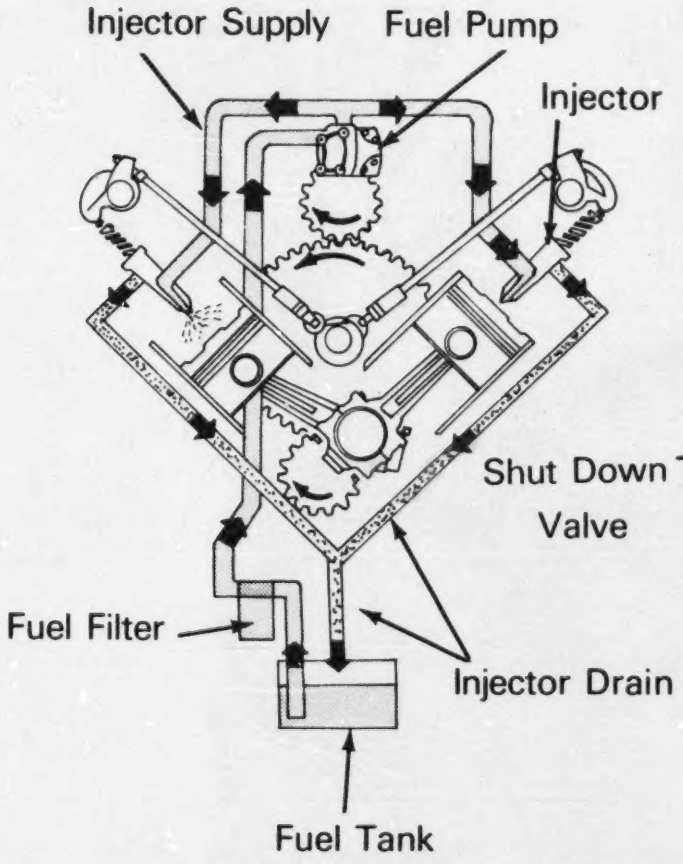
1. Plunger remains seated after injection

   (NOTE: Fuel flows through the injector cooling it and warming tank fuel through this stage.)

2. Plunger rises on next metering operation

   (NOTE: The timing of metering and injection is determined by camshaft configuration.)

Main Parts Of PT Fuel System



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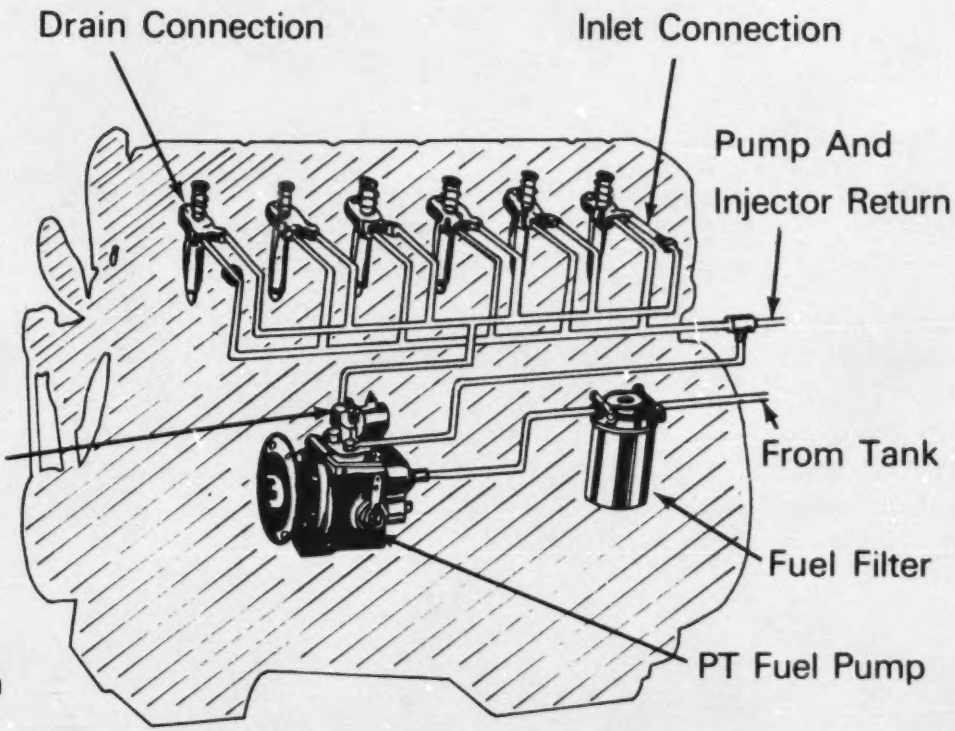

FUEL FLOW DIAGRAM OF CUMMINS PRESSURE TIME INJECTION SYSTEM.

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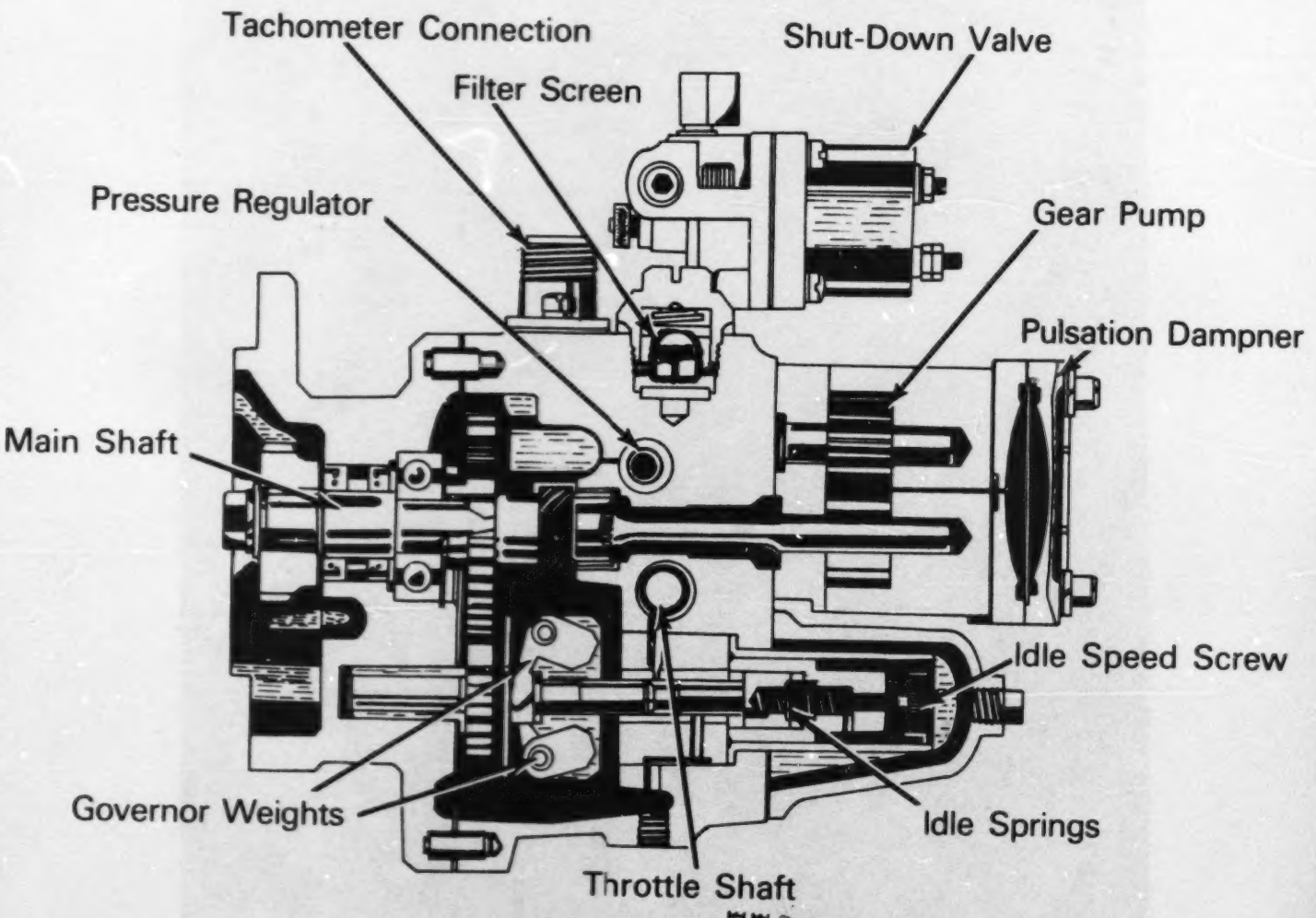
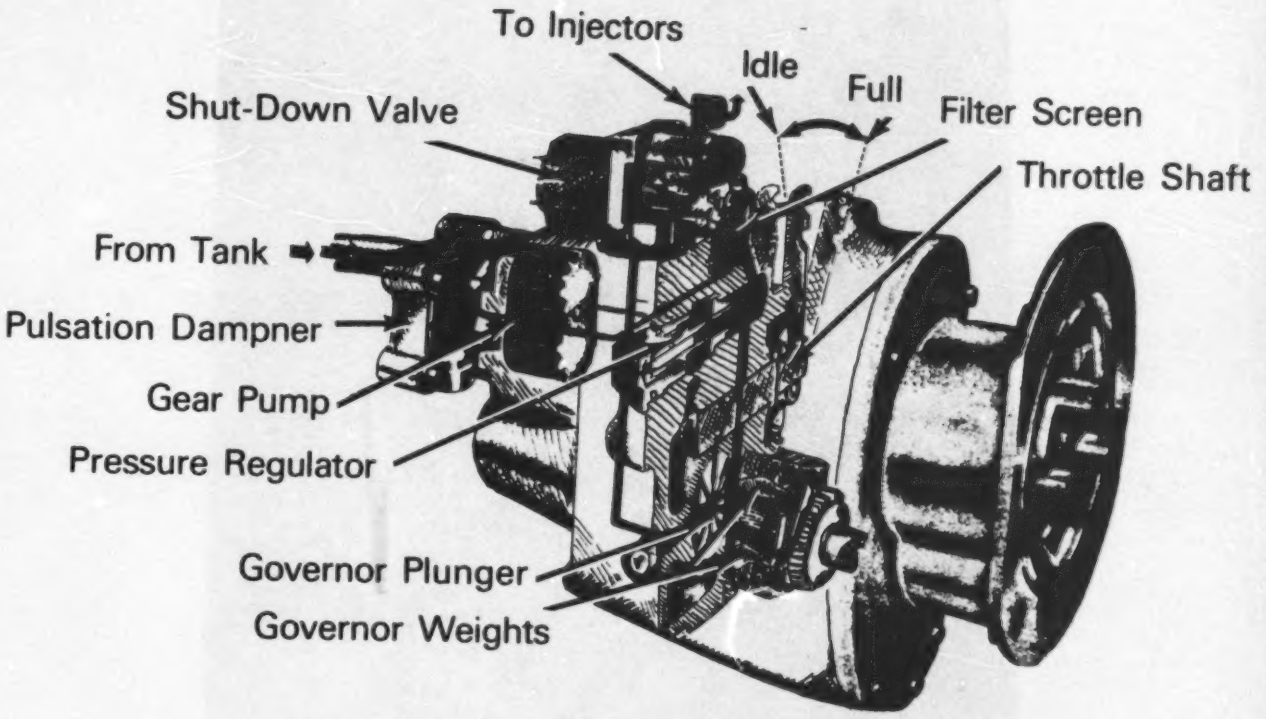
PT Pump Assembly



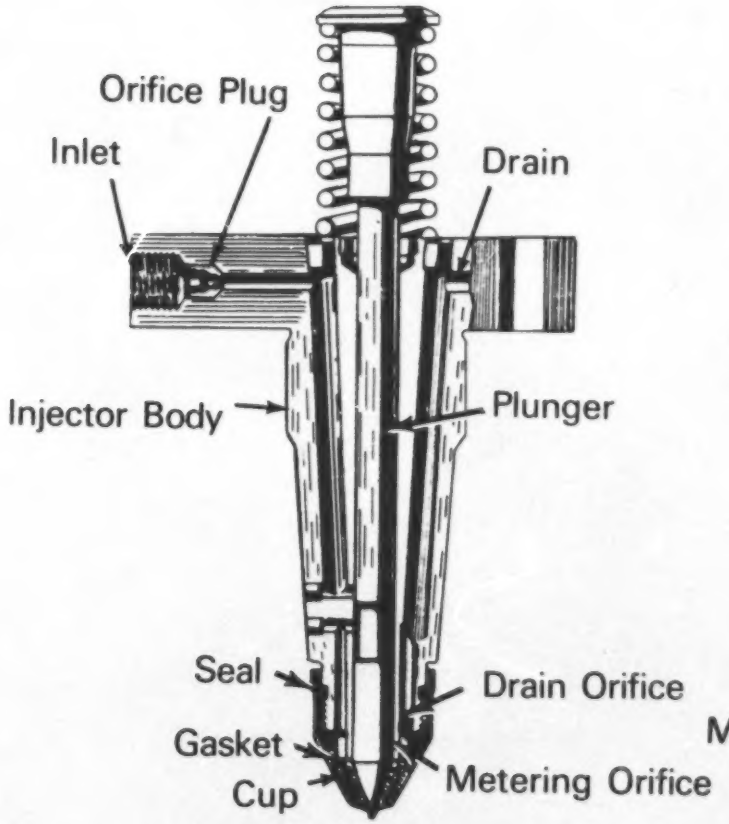
PT Pump Assembly

(Continued)

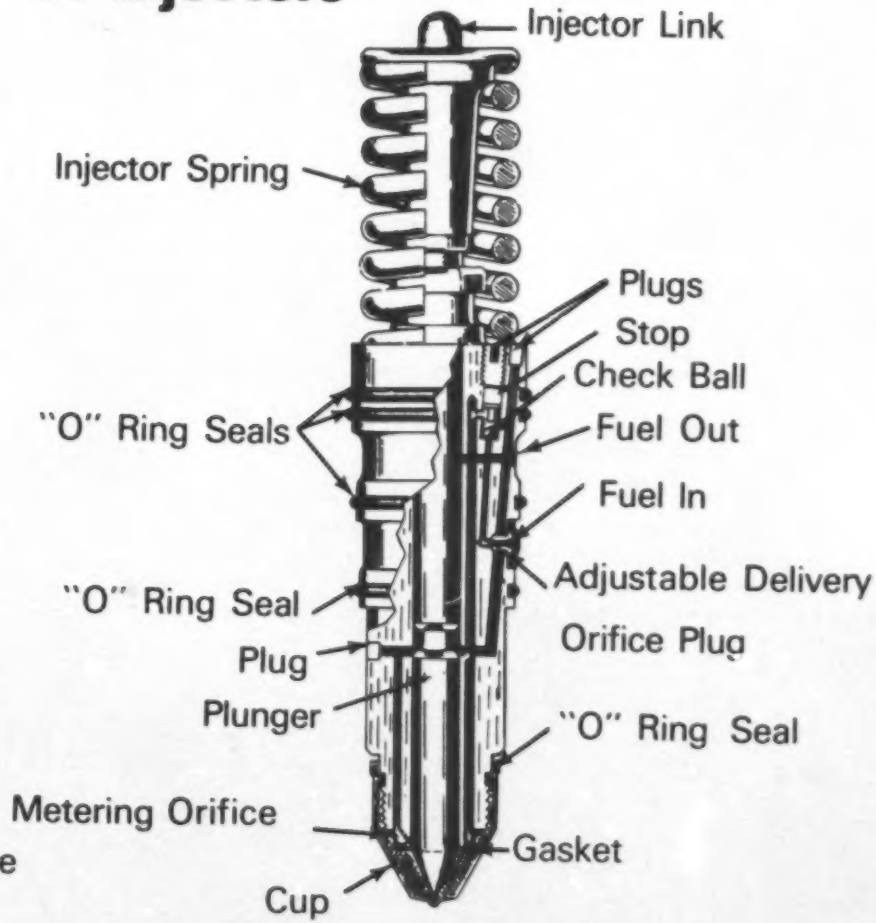


CUMMINS PT TYPE R FUEL INJECTION PUMP.

Types Of Injectors



FLANGED TYPE INJECTOR



CYLINDRICAL INJECTOR

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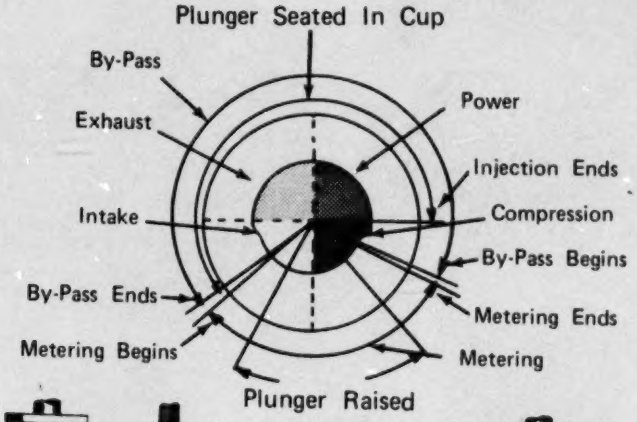
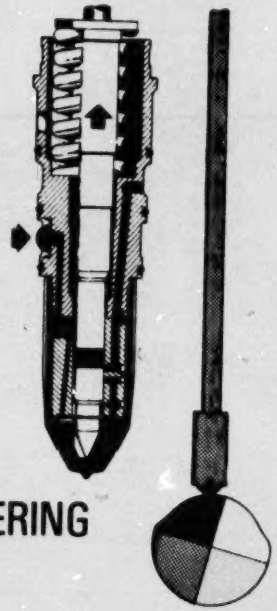
Operation Of Injectors





METERING

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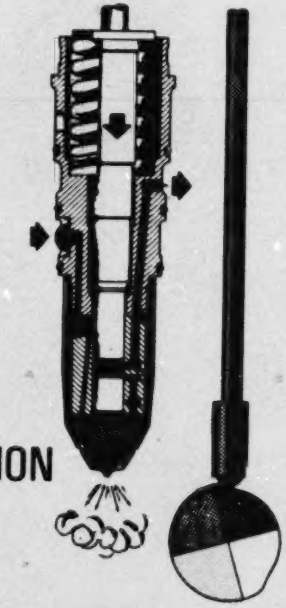
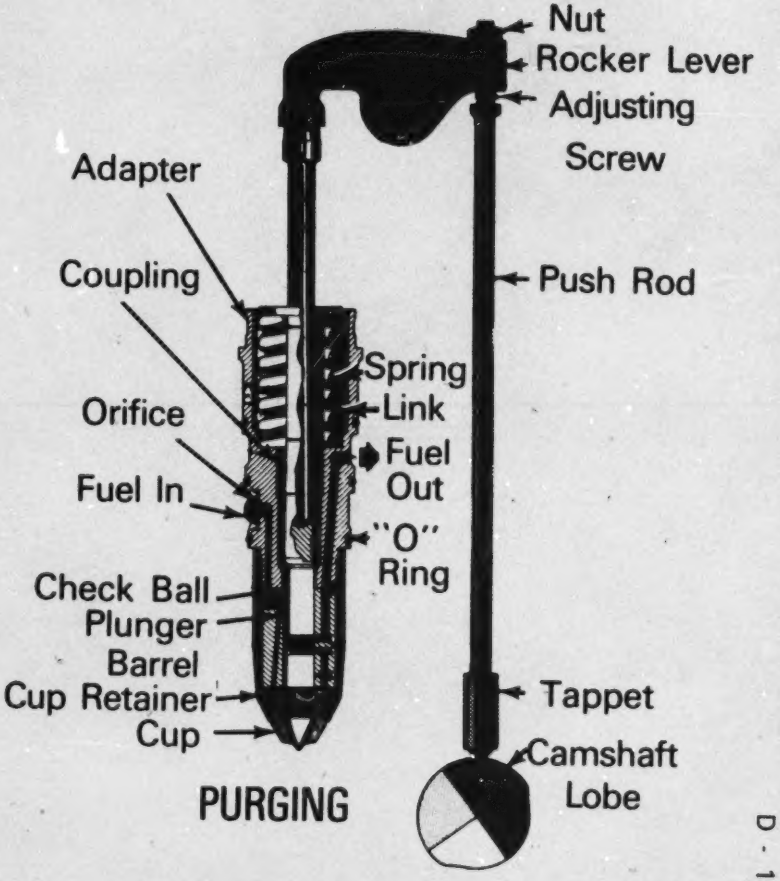


INJECTION



PURGING

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TM 5

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PT FUEL SYSTEMS
UNIT V

JOB SHEET #1--REMOVE AND INSTALL FLANGE TYPE PT INJECTORS

I. Tools and materials

A. Basic hand tool set

B. Torque wrench

C. Oil can, hand type

D. Shop towels

E. Safety glasses

II. Procedure

A. Remove injector

1. Remove injector hold-down camscrews

2. Pry and remove injector from cylinder head by grasping injector body rather than plunger

(NOTE: Do not turn injector upside down, as plunger might drop out.)

3. Place in drain rack

(NOTE: Do not damage injector tip and be careful not to lose the plate retaining collet. Do not intermix plunger and injector bodies as they are paired.)

B. Install injector

1. Clean injector seat with clean rag wrapped around wooden stick

(NOTE: Never use screwdriver or metal tool for this operation; a scratched seat may cause compression leakage.)

2. Position injectors in head(s)

(NOTE: When installing injectors in head(s), position injector plunger so class mark is centered between inlet and drain connections. This provides the same plunger position under which the injector was tested in injector test stand. Be careful not to damage injector tips.)

JOB SHEET #1

3. Oil injector hold-down capscrews

4. Start, but do not tighten, hold-down capscrews into injector mounting holes in cylinder head(s)

5. Align injectors before tightening hold-down capscrews by screwing in the inlet and drain connections about three turns

6. Torque to 10 to 12 ft-lb (14 to 16 N. m) in alternate steps

7. Start tightening on capscrews opposite inlet and drain connection

   (NOTE: Some injector hold-down capscrews contain a Nylok insert that acts as a lock. These capscrews may be reused 5 to 10 times before the effectiveness of the insert is impaired. Nylok capscrews should be torqued to 12 to 14 ft-lb (16 to 19 N. m).)

8. Torque inlet and drain connections to 20 to 25 ft-lb (27 to 34 N. m)

9. Check air on tubes

   (NOTE: Put in new copper washers. Check boots and filter screen.)

PT FUEL SYSTEMS
UNIT V

JOB SHEET #2--REMOVE AND INSTALL PT (TYPE B, C, AND D) INJECTORS

I. Tools and materials

A. Basic hand tool set

B. Torque wrench

C. Oil can, hand type

D. Shop towels

E. Safety glasses

II. Procedure

A. Remove injector (type B and C)

1. Remove hold-down capscrews

2. Insert 3/8"-16 capscrew in tapped hole in hold-down plate and jack injector from head

3. Place injectors in rack for protection

4. Tag and number injectors by cylinder from which removed

(CAUTION: Do not damage injector tips.)

(NOTE: Older model engines have a separate jacking hole in the plate and utilize a standard hold-down capscrew for the jacking action.)

B. Install injectors (type B and C)

1. Clean injector sleeve with cloth wrapped around wooden stick

2. Lubricate the injector body "O" rings with clean S.A.E. 20 or 30 lubricating oil

(NOTE: The "O" rings should receive a fresh coat of oil each time injectors are installed in head.)

3. Start the injector into bore, guiding by hand until injector is aligned in bore and not binding in any manner

(NOTE: To install injectors on V-12 engines, stand either on right bank side or left bank side of engine. On H or NH engines, install injectors from fuel pump side of engine. Injectors are to be placed with ball check retainer plug at one o'clock.)

JOB SHEET #2

4. Place plastic hammer handle butt on top of injector plunger body and "seat" injector by giving a quick, hard push on the hammer

   (NOTE: A "snap" should be heard and felt as the cup seats in the copper sleeve.)

5. Place hold-down plate over injector body with counterbore up

6. Position half-collet locking clamp in injector body groove

7. Start hold-down capscrews, but do not tighten

   (NOTE: Be sure the two projecting radii, do not drop in drilled holes atop injector.)

8. Place injector spring on hold-down plate with closed end down

   (NOTE: Spring must seat on hold-down plate. If spring seats on locking clamp, incorrect injector adjustment will result, causing push tube and camshaft damage.)

9. Hold injector spring in position and carefully insert injector plunger

   (NOTE: On V-12 engines only, position plunger in injector bore with class mark on the plunger midway between inlet and drain ports of injector the inlet port is below the ball retainer plug. This will provide the same operating position in which the injector was calibrated.)

10. Torque procedure for V-12 engines only

    a. Make sure injector is positioned correctly in head

    b. Tighten one capscrew (use Nylok capscrews) until clamp contacts head snugly; then back out one complete turn

    c. Tighten other capscrew to a torque of 4 to 5 ft-lb (5 to 7 N. m)

    d. Tighten first capscrew to 7 to 8 ft-lb (9 to 11 N. m)

    e. Tighten second capscrew to 7 to 8 ft-lb (9 to 11 N. m)

    f. Check the plunger to see if it is free

JOB SHEET #2

g. Loosen clamp and retorque if the plunger is not free

(NOTE: On H and NH engines, position plunger in injector bore with class mark on the plunger toward rear of engine. This will provide the same operating position in which the injector was calibrated.)

11. Torque hold-down capscrews in alternate steps to 11 to 12 ft-lb (15 to 16 N. m)

C. Remove and install PT (type D) injectors

1. Remove injector hold-down plate or yoke

(NOTE: On some engines special tools are needed to remove injectors, consult appropriate service manual.)

a. On NH, NT, and V12 series engines you may insert a 3/8-16 capscrew in tapped hole in hold-down plate and jack injector from head

b. Use a right angle roll bar or pinch bar to pry injectors from head in "V" series engines

(NOTE: When prying up, be certain to keep the plunger and/or injector from jumping out of the head and landing on the floor.)

2. Remove all carbon from injector copper sleeves

(NOTE: Do not use anything metal to scrape the sleeves. Use a wooden stick with a clean cloth wrapped around the end.)

3. Lubricate the "O" rings with 20 to 30 weight lube oil. Do not use Lubriplate

4. Start injector into bore, guiding by hand until aligned in bore and not binding

(NOTE: It is not required to line up any plugs or rotate injector around in any position. The PT (type D) will perform at any position.)

5. Place a clean blunt object on injector body and "seat" injector by giving a quick hard push

JOB SHEET #2

6. Listen for the snap as cup seats in copper sleeve

(NOTE: Do not use a wooden hammer handle or similar tool to install injectors. Dirt or splinters from the handle may drop into plunger link seat causing early failure of link or plunger socket. If injector is not completely seated, the "O" rings may be damaged if pulled down with the mounting capscrews.)

7. Install hold-down plates or yokes, lockwashers, and capscrews

(NOTE: Be certain plates or yokes do not contact crosshead stems.)

8. Torque NH, NT, and KT capscrews in alternate steps to 11-12 ft-lb (15 to 16 N. m)

   a. Use Nylok capscrews on V-12 engines and torque alternately to 11 to 12 ft-lb (15 to 16 N. m)

   b. Torque V-6-140, V-8-185, V-378, V-504, V-555, V-8-265 and V-903 capscrews to 30 to 35 ft-lb (41 to 47 N. m)

9. Test injector plunger for movement after torqueing hold-down capscrews. If plunger is not free, loosen and retorque capscrews

PT FUEL SYSTEMS
UNIT V

JOB SHEET #3--ADJUST INJECTOR PLUNGER AND VALVES USING TORQUE METHOD

I. Tools and materials

A. V-378, V-504, V-555, or VT-555 C.I.D. series Cummins engine

(NOTE: For specific installation and models get detailed service and specifications from the manufacturer's service bulletin.)

B. Basic hand tool set

C. Inch-pounds torque wrench

D. Foot-pounds torque wrench

E. Feeler gauge

F. Shop towels

G. Safety glasses

II. Procedure

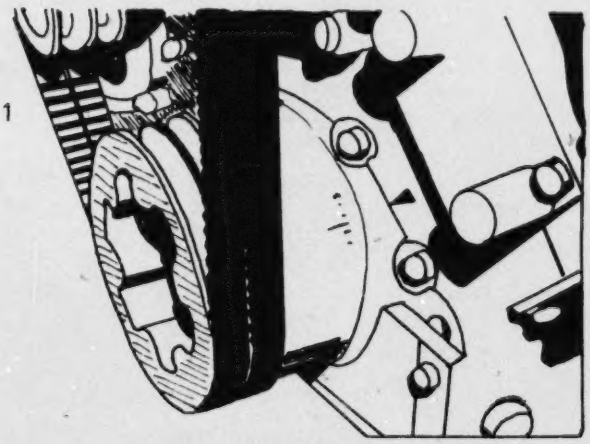
(NOTE: Retorque injector hold-down clamp cap screws to manufacturer's specifications before adjusting injectors.)

A. Position valves and mark alignment

1. Turn crankshaft in direction of rotation until No. 1-6 "VS" mark appears on the vibration damper or crankshaft pulley (Figure 1)

(NOTE: Some models may have "A" marked on damper.)

FIGURE 1



JOB SHEET #3

(NOTE: In this position, both intake and exhaust valves must be closed for cylinder No. 1; if not, advance crankshaft one revolution. See Figures 2 and 3 and Table 1 for firing order.)

FIGURE 2

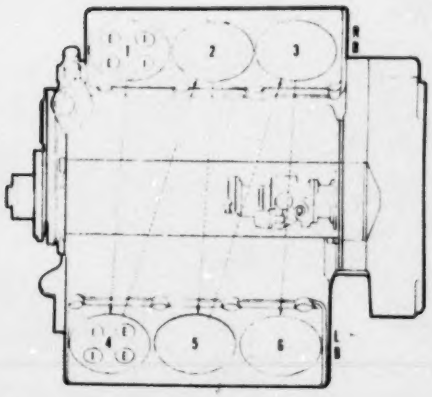


FIGURE 3

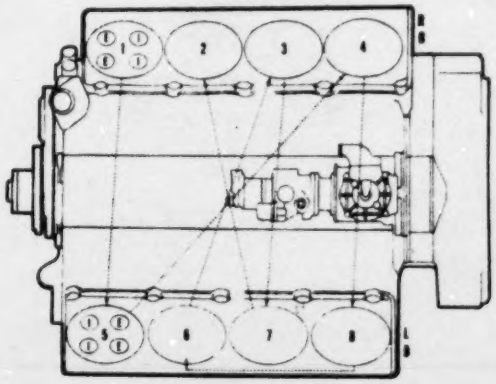


Table 1: Engine Firing Order

Right Hand Rotation	V8	1-5-4-8-6-3-7-2
Right Hand Rotation	V6	1-4-2-5-3-6

2. Adjust injector plunger, then crossheads and valves of first cylinder as explained in the following steps

3. Turn crankshaft in direction of rotation to next "VS" mark corresponding to firing order of engine and corresponding cylinder will be ready for adjustment (See Table 1)

4. Continue turning crankshaft in direction of rotation and making adjustments until all injectors and valves have been correctly adjusted

   (NOTE: Two complete revolutions of crankshaft are needed to set all injector plungers and valves. Injector and valves can be adjusted for only one cylinder at any one "VS" setting.)

B. Adjust crosshead

1. Loosen valve crosshead adjusting screw locknut and back off screw one turn

2. Use light finger pressure at rocker lever contact surface to hold crosshead in contact with valve stem (without adjusting screw)

JOB SHEET #3

3. Adjust crosshead adjusting screw according to engine manufacturer's specifications (Figure 4)

FIGURE 4

4. Hold adjusting screw in this position and torque locknut to values specified in appropriate service manual (Table 2)

Table 2: Crosshead Locknut Torque

Without ST-669	With ST-669
25 to 28 ft-lbs (34 to 38 N. m)	22 to 26 ft-lbs (30 to 35 N. m)

C. Adjust injector plunger

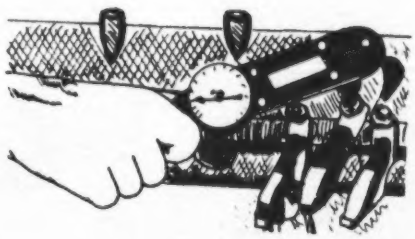
1. Turn adjusting screw down until plunger contacts cup and advance an additional 15° to squeeze oil from cup

2. Loosen adjusting screw one turn

3. Using a torque wrench calibrated in in-lbs and a screwdriver adapter, tighten the adjusting screw to values shown in Table 2 for cold setting and tighten the locknut to manufacturer's specification figures (Figure 5)

JOB SHEET #3

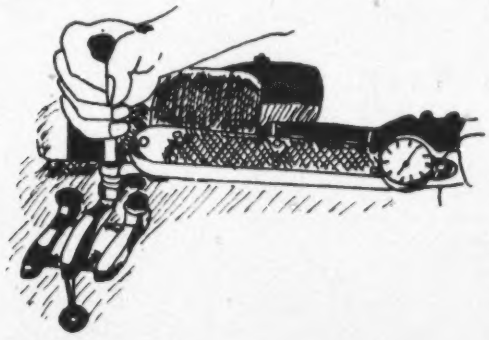
FIGURE 5



(NOTE: Some engines use different hot and cold torque settings.)

4. Hold injector adjusting screw and tighten injector adjusting screw locknut to value specified in appropriate service manual (Figure 6)

FIGURE 6



D. Adjust valves

(NOTE: The same crankshaft position used in adjusting injectors is used for setting intake and exhaust valves.)

1. Loosen locknut and back off adjusting screw

2. Insert feeler gauge between rocker lever and top of crosshead

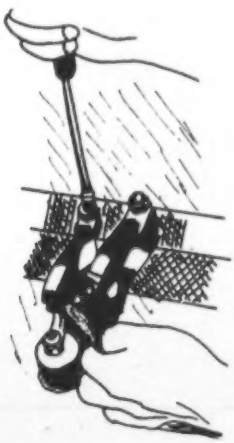
(NOTE: Consult appropriate service manual for exact specifications.)

JOB SHEET #3

3. Turn screw down until lever just touches gauge and lock adjusting screw in this position with locknut (Figure 7)

4. Torque locknut to values indicated in service manual

FIGURE 7



PT FUEL SYSTEMS
UNIT V

JOB SHEET #4--INSTALL PT-R FUEL PUMP AND ADJUST HIGH AND LOW ENGINE IDLE

I. Tools and materials

A. Basic hand tool set

B. Cummins engine using PT-R fuel pump

C. PT-R fuel pump properly calibrated

D. Hand tachometer

E. Idle adjusting tool

F. Shop towels

II. Procedure

A. Install pump

(NOTE: Injectors and values should be set to specifications and engine warmed to operating temperature.)

1. Install fuel pump to accessory drive or to compressor with new gasket and proper rubber buffer, nylon buffer or spline coupling and tighten securely

2. Squirt some clean lube oil into gear pump inlet hole

(NOTE: This aids gear pump fuel pick-up.)

3. Connect the fuel pump copper line from the pump shut-off valve to the fuel manifold

(NOTE: The throttle lever linkage should not be connected to the throttle lever, thus leaving the throttle free for pump adjustments.)

4. Install tachometer to fuel pump tachometer drive shaft connection or use hand tachometer

5. Connect the shut-off valve electrical connections properly, leaving the manual control button in a closed position (screwed out)

6. Connect pump drain line to housing

JOB SHEET #4

B. Set governor

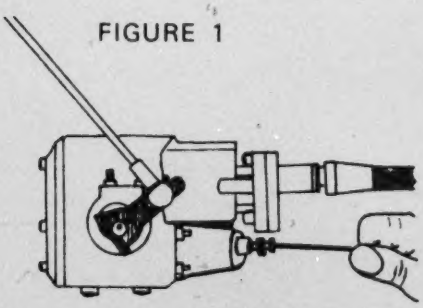
1. Set idle speed

a. Operate engine a sufficient period of time to purge air from the fuel system and to bring engine up to operating temperature (at least 165° F. oil temperature)

b. Remove pipe plug from spring pack cover

c. Install idle adjusting tool (Figure 1)

FIGURE 1



d. Operate engine a sufficient period of time to purge all air from the fuel system after idle adjusting tool is installed in spring pack cover

e. Turn idle adjusting screw in to increase or out to decrease the speed

(NOTE: The idle adjusting screw is held in position by a spring clip. Consult appropriate service manual for exact idle speeds.)

f. Remove idle adjusting tool and replace pipe plug when idle speed is correct

(NOTE: On the mechanical variable speed governor fuel pump the maximum and idle adjusting screws are located on governor cover; adjust idle by loosening rear idle adjusting screw locknut. Screw adjusting screw in or out to get speed required. Tighten adjusting screw locknut immediately after adjustment to prevent air entrainment.)

JOB SHEET #4

2. Set rated speed

(NOTE: The engine should be "loaded" on an engine or chassis dynamometer to perform this check. Normally, this adjustment is made on the fuel pump test stand as the fuel pump is calibrated and does not need to be changed on the engine.)

3. Set engine hi-idle or maximum no-load speed

(NOTE: This check should not be used to check or make governor speed adjustments. If the hi-idle speed is significantly greater than specifications, the governor assembly should be examined for malfunction or improper parts.)

PT FUEL SYSTEMS
UNIT V

JOB SHEET #5--TEST AND ADJUST PT-G FUEL PUMP

(NOTE: The job sheet detailed here is general and requires the use of test stand manual, pump specifications sheet and the appropriate engine service manual.)

I. Tools and materials

- A. Basic hand tool set
- B. Test stand and adapters
- C. Test stand manual
- D. Pump special tools
- E. PT-G fuel pump
- F. Pump specification sheet
- G. Lint free shop towels
- H. Eye protection

II. Procedures

- A. Thoroughly clean pump exterior
- B. Drain all fuel from pump and fill with pump stand oil
- C. Mount pump as described in pump mounting section of manual

  (NOTE: Run all tests with fuel temperature at 90° F.)

- D. Test--Pump run-in

  1. Determine pump rotation with stand in high range
  2. Open pump shutdown valve, manifold valve, and suction valve on pump
  3. Close idle valve and bypass valve on pump discharge line
  4. Turn on pump stand and run up to 500 rpm for pump to pick up prime
  5. Run pump to rated speed for 5 minutes to seat bearings, flush pump, and purge air
  6. Check for air in flow meter

JOB SHEET #5

E. Test--Gear pump suction--Operate test stand at 500 rpm and close suction valve to 25" vacuum

F. Test--Pump suction adjustment

1. Turn stand to 100 rpm below rated speed

2. Adjust suction valve to 8" vacuum for remainder of tests

G. Test--Total fuel flow

1. Open manifold valve

2. Close idle and bypass valves

3. Set suction valve to 8" vacuum

4. Raise test stand speed to PT-G pump rated speed given on calibration sheet

5. Adjust manifold valve until flow meter float indicates the flow specified under "flowmeter-lb. hr. @ rpm" on the calibration sheet

H. Test--Governor cut-off speed

1. Place throttle in full fuel position

2. Increase test stand speed to a point where pressure begins to drop and check pump speed which should be within limits for "Governor Cut-Off RPM" on calibration sheet

(NOTE: If speed is outside limits, add shims on high speed governor spring. Remove shims to lower speed. Each .001" of shim will change 2 rpm.)

3. After adjusting Governor Cut-Off RPM raise stand speed until Pressure Gauge drops to 40 PSI or what's stated under "Governor Setting PSI-RPM" in specification sheet

(NOTE: If more than 10-15 rpm higher, a change in governor barrel and plunger may be needed.)

I. Test--Throttle leakage

1. Operate a test stand at rated speed and flow

2. Hold throttle in idle position with throttle spring

3. Open bypass valve and close manifold valve

JOB SHEET # 5

4. Place "graduate" under bypass tube and collect fuel for 30 sec.

5. Compare doubled amount to specification sheet and adjust front screw to required amount

   (NOTE: If leakage cannot be reduced to correct leakage, excess wear to throttle shaft is indicated.)

6. Lock screw when setting is correct

J. Test--Idle fuel pressure

1. Reduce test stand speed to 500 rpm or speed stated on specification sheet

2. Open idle valve and close manifold and bypass valve

3. Hold throttle in idle position

4. Note reading on pressure gauge

5. Adjust idle screw in spring back cover to correct pressure

   (NOTE: Screw in to increase and out to decrease pressure.)

6. Purge air after each setting

K. Test--Manifold fuel pressure

1. Open manifold valve and close idle and bypass valve

2. Place throttle in full fuel position

3. Run stand at rated speed and adjust manifold valve to total fuel flow

   (NOTE: Pressure should agree to specification, adjust shims in throttle shaft to read 3 to 6 PSI higher than specification sheet.)

4. Reset flow meter to specifications

5. Turn in rear throttle screw to trim off 3 to 6 PSI and bring pump to specification

6. Recheck governed speed and pressure

JOB SHEET #5

L. Check point pressure

1. Reduce stand speed to "Check Point" speed
2. Check manifold pressure at check point speed, if above or below, check torque spring for seating, shimming and part no.
3. If spring is changed recalibrate pump

M. Check weight assist pressure

1. Reduce stand speed to 800 rpm

   (NOTE: Manifold pressure should fall within specification under "Weight Assist PSI.")

2. Add shims in governor weight carrier to raise pressure
3. Remove shims to lower pressure
4. If shims are changed, recalibrate pump

N. Drain and remove pump from test stand when calibration is complete

O. Seal all openings in pump

PT FUEL SYSTEMS
UNIT V

NAME _____

TEST

1. Match terms on the right to the correct definitions.

_____a.	Pressure time system based on the principle that the volume of liquid flow is proportionate to the fluid pressure, the time allowed to flow, and the size of the passage through which the liquid flows	1.	Purge
		2.	Meter
		3.	PT type G
		4.	PT type R
_____b.	PT fuel pump which is governor controlled	5.	Rated speed
_____c.	PT fuel pump which is pressure regulated	6.	PT system
_____d.	To get rid of trapped fuel	7.	High idle or maximum no load speed
_____e.	Engine rpm's under full load		
_____f.	To supply in a measured amount		
_____g.	Engine rpm's with no-load and throttle fully open		

2. Name the three main parts of the PT fuel system.

a.

b.

c.

3. Match the main units of the PT pump assembly on the right to their functions.

_____a.	Draws fuel from supply tank forcing it through the pump filter screen into the pressure regulator valve	1.	Pressure regulator
		2.	Gear pump
_____b.	Limits the pressure of the fuel to the injectors	3.	Governor assembly
_____c.	Provides a manual control of fuel flow to the injector under all conditions in the operating range	4.	Throttle
_____d.	Controls the flow of fuel from idle to maximum governor speed		

4. Discuss the operation of the PT injection system.

5. State the function of the pulsation damper.

6. Explain the operation of the mechanical governor.

7. Name two types of PT injectors.

   a.

   b.

8. Match the operational steps of the PT injectors at the right to their description on the left.

_____a.	1)	Fuel enters the injector at fuel inlet	1. Injection
			2. Metering
	2)	Metering orifice controls quantity of fuel that enters the injector cup	3. Purging

_____b. 1) Downward plunger movement cuts off fuel entry into injector cup

2) Continued downward movement forces fuel from injector cup through the orifice into combustion chamber

3) While plunger is down fuel passes through upper hole around undercut in plunger through return passages to the fuel tank

_____c. 1) Plunger remains seated after injection

2) Plunger rises on next metering operation

9. Demonstrate the ability to:

a. Remove and install flange type PT injectors

b. Remove and install PT (type B, C, and D) injectors.

c. Adjust injector plunger and valves using torque method.

d. Install PT-R fuel pump and adjust high and low engine idle.

e. Test and adjust PT-G fuel pump.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

PT FUEL SYSTEMS
UNIT V

ANSWERS TO TEST

1. a. 6
   b. 3
   c. 4
   d. 1
   e. 5
   f. 2
   g. 7
2. a. Fuel pump
   b. Supply lines, drain lines, and passages
   c. Injectors
3. a. 2
   b. 1
   c. 4
   d. 3
4. Discussion should include:
   a. Gear type fuel pump delivers fuel through a restricting throttle to the governor
   b. From the governor, the fuel goes to a manifold which feeds cam-operated injectors in the cylinder head
   c. Injector raises pressure to produce a good spray and times the start of injection
5. The damper contains a steel diaphragm which absorbs pulsations and smooths fuel flow through system
6. Explanation should include:
   a. Between idle and maximum speed, fuel flows through the governor to the injector in accordance with engine requirements as controlled by the throttle

b. When engine reaches governed speed, the governor weights move the governor plungers so fuel passage to the injectors is shut off

c. Fuel leaving the governor flows through the shut down valve, inlet supply lines, and onto the injectors

7. a. Flanged

b. Cylindrical

8. a. 2

b. 1

c. 3

9. Performance skills evaluated to the satisfaction of the instructor

INJECTION NOZZLES
UNIT VI

UNIT OBJECTIVE

After completion of this unit, the student should be able to explain the operation and list the functions of the injection nozzle. The student should also be able to match characteristics to the type of various spray valves. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with injection nozzles to the correct definitions.
2. List two functions of the injection nozzle.
3. Name four moving parts in the injection nozzle.
4. Name three common types of nozzle valves.
5. Match the types of nozzles to their characteristics.
6. Explain the operation of the injection nozzle.
7. Explain how the nozzle opening pressure is adjusted.
8. Demonstrate the ability to remove, service, and test an injection nozzle.

INJECTION NOZZLES
UNIT VI

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined in the job sheet.

G. Demonstrate lapping and cleaning procedures.

H. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete job sheet.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Moving Parts in Nozzle

2. TM 2--Nozzle Valve Assembly

D. Job Sheet #1--Remove, Service, and Test an Injection Nozzle

E. Test

F. Answers to test

II. References:

A. Toboldt, Bill. *Diesel: Fundamentals, Service, Repair.* South Holland, Illinois: Goodheart-Willcox Company, 1973.

B. Kates, Edgar J., and Luck, William E. *Diesel and High Compression Gas Engines.* Chicago: American Technical Society, 1974.

C. *Fundamentals of Service: Engines.* Moline, Illinois: Deere and Company, 1972.

D. Robert Bosch Corporation. Bulletin Number 221103. 4131-A Directors Row, Houston, Texas 77018.

INJECTION NOZZLES
UNIT VI

INFORMATION SHEET

I. Terms and definitions

- A. Pintle--Valve in which the end extends into a shank or pin
- B. Orifice--Small hole
- C. Injector nozzle--Nozzle, nozzle holder, valve and spring assembly
- D. Nozzle assembly--Valve, body, and spray valve

II. Functions of the injection nozzle

- A. Atomizes the fuel for better combustion
- B. Spreads the fuel spray to fully mix with air

III. Moving parts (Transparency 1)

- A. Valve
- B. Spring
- C. Spindle
- D. Retainer

IV. Types of common nozzle valves (Transparency 2)

- A. Single hole
- B. Multiple orifice
- C. Pintle type, single hole

V. Nozzle characteristics (Transparency 2)

- A. Hole type--Used for engines with open combustion chambers
- B. Pintle type (inward-opening)--Produces a hollow spray; used for engines with precombustion chambers or energy cells
- C. Pintle type (outward-opening)--Does not dribble fuel; used for engines with precombustion chamber or energy cell
- D. Multiple orifice--Variation of pintle type; holes have a tendency to clog

VI. Operation of injection nozzle

- A. Hydraulically operated by fuel delivered from the injection pump

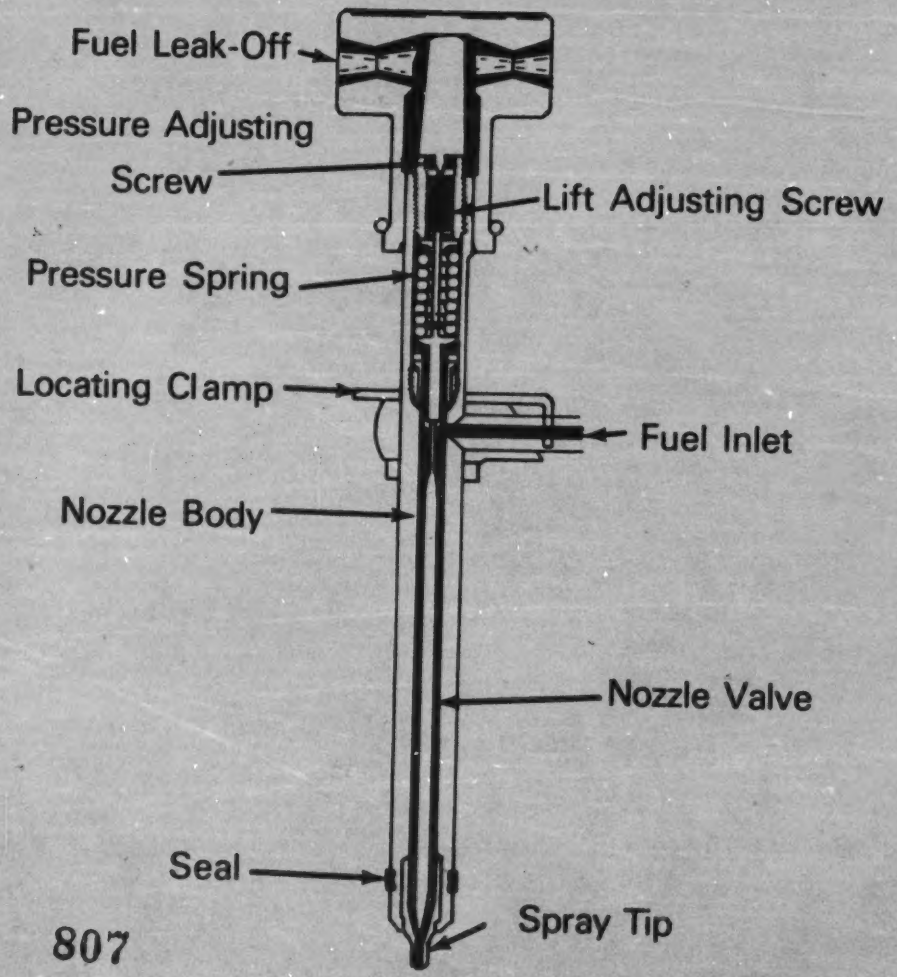
INFORMATION SHEET

B. Spring loaded valve is lifted allowing pressurized fuel to spray out through one or more orifices into combustion chamber

(NOTE: Some injection nozzles have adjustable valve lifts. Refer to manufacturer's service manual.)

VII. Adjustment of nozzle opening pressure--Adjusted by a screw or shims on the valve spring (Transparency 1)

Moving Parts In Nozzle



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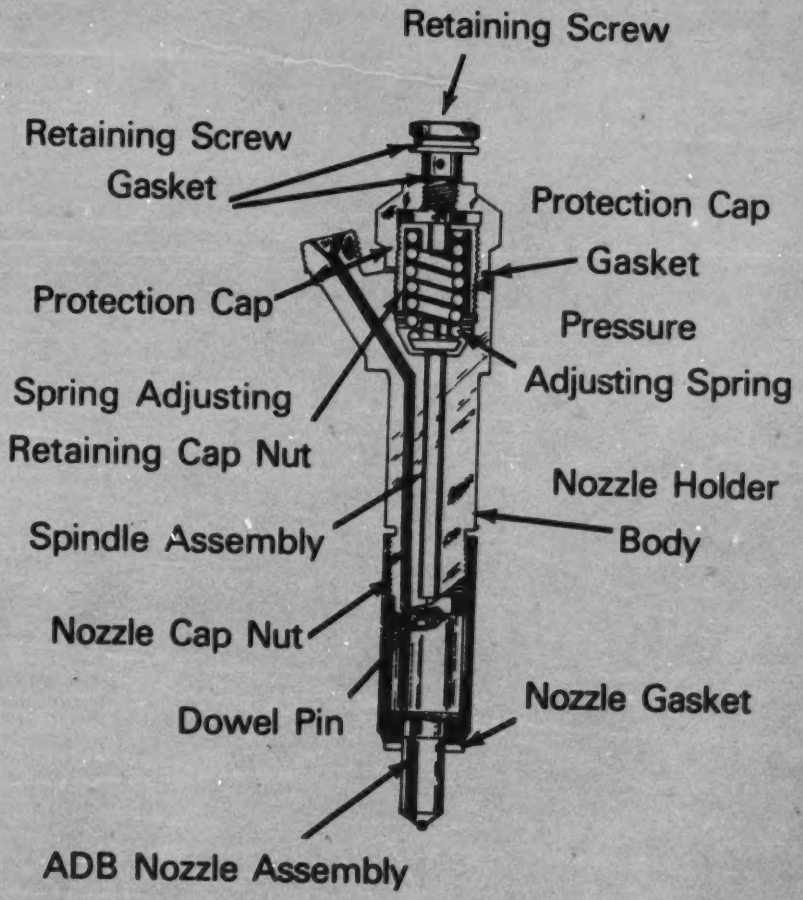

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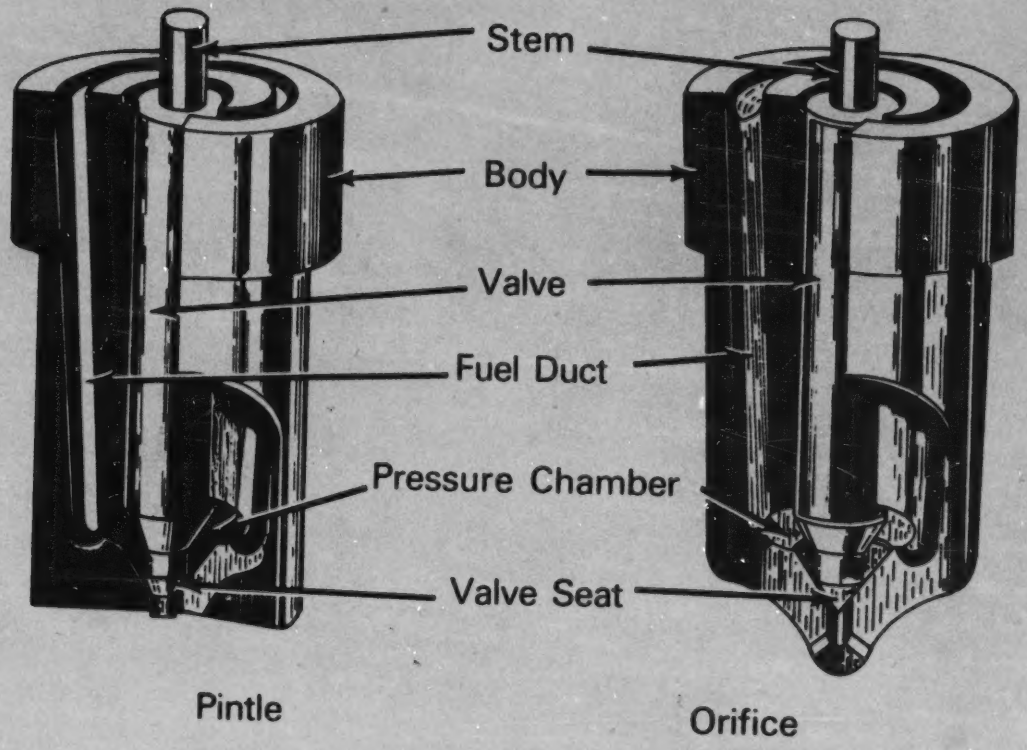
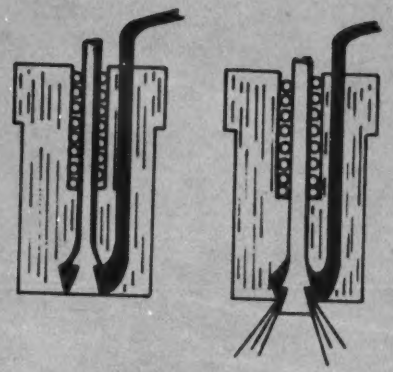
Nozzle Valve Assembly



Pintle

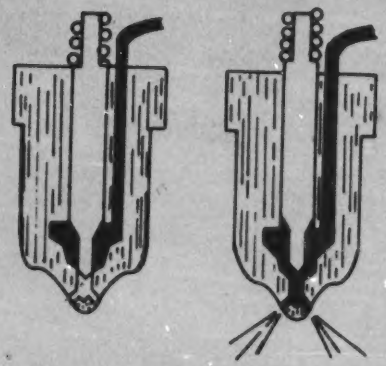
Orifice



Closed Open

Outward-Opening

Pintle-Type



Closed Open

Inward-Opening

Hole-Type

INJECTION NOZZLES
UNIT VI

JOB SHEET #1--REMOVE, SERVICE, AND TEST AN INJECTION NOZZLE

I. Tools and materials

A. Nozzle tester

B. Appropriate service tool kit

II. Procedure

(NOTE: The job sheet detailed here is general. For specific installations and models follow the specifications and procedures according to the engine manufacturer's instruction manual.)

A. Remove nozzle

1. Clean the area around the nozzle

2. Remove and cap the injection and leak-off lines

3. Remove the nozzle from the engine

(NOTE: Some nozzles may require special tools or procedures for removal. See manufacturer's service manual.)

B. Clean nozzle

1. Soak entire nozzle assembly in clean solvent or calibration fluid after discarding outer seals

2. Clean and decarbon spray tip and nozzle body with a brass wire brush (Figure 1)

(NOTE: Never use emery cloth or steel wire brush because the precision tip will be damaged.)

FIGURE 1

JOB SHEET #1

C. Test nozzle

(NOTE: All nozzles require careful handling and a special tool kit to perform any service. When working on several nozzles, DO NOT mix nozzle parts.)

1. Place nozzle into nozzle holder

2. Tighten nozzle nut, first by hand, then with correct size wrench

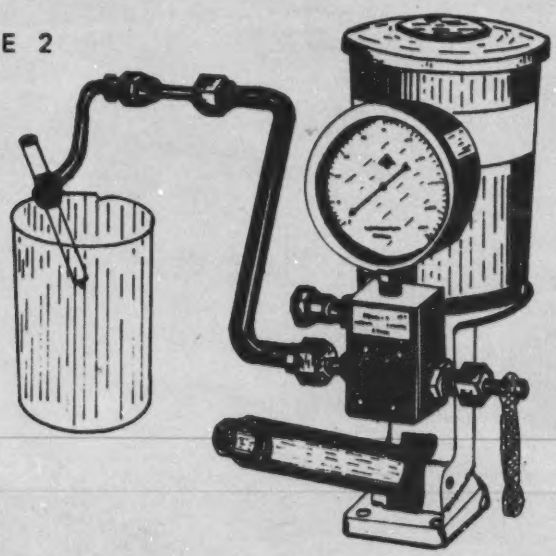
3. Torque nozzle nut according to the values given by the engine manufacturer's specification

4. Connect the nozzle holder with the delivery line to the tester

5. Enclose nozzle in transparent beaker, if possible (Figure 2)

(CAUTION: The fuel comes out of the nozzle at extremely high-pressure which can penetrate clothing and skin and cause injury. Always keep the nozzle pointed away from you or enclose in beaker.)

FIGURE 2



6. Test for nozzle jamming by pressing hand lever of nozzle tester down quickly (6-8 times) with the pressure gauge bypassed

(NOTE: When valve moves properly, the nozzle should chatter with a shrill whistling buzz. An exception to the rule is the type nozzle with one or two small spray holes that will not chatter when lever is operated quickly.)

JOB SHEET #1

7. Open pressure gauge

8. Slowly depress hand lever until the nozzle ejects with slight chatter

9. Take reading of opening pressure on the pressure gauge

(NOTE: Adjust to opening pressure specified in the engine operating instructions.)

10. If reading differs from specified opening pressure, turn adjusting screw, (Figure 3), or change total shim thickness (Figure 4)

(NOTE: Opening pressure is not adjusted by shims on all models.)

FIGURE 3

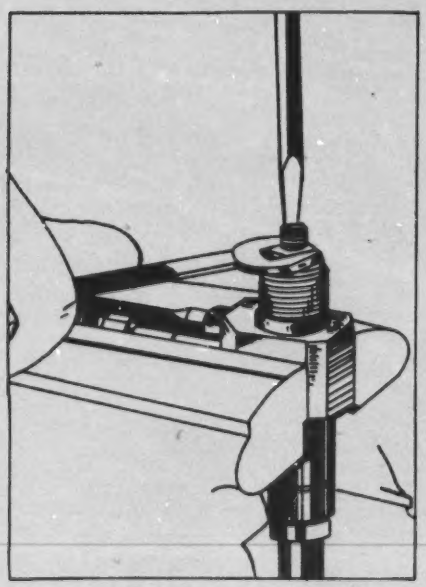
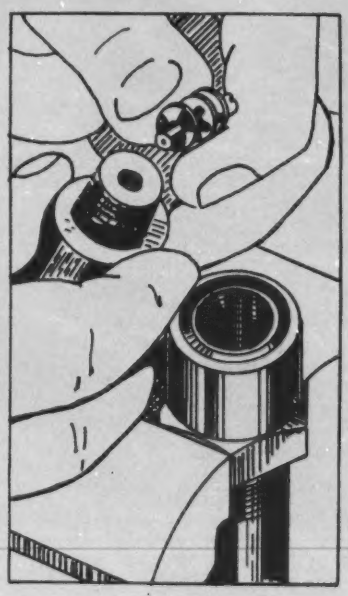


FIGURE 4



D. Test leakage--Operate the hand lever of the nozzle tester until the pointer on the pressure gauge indicates 285 psi below the specified opening pressure

(NOTE: The nozzle is considered leakproof if no oil emerges at the nipple tip within 10 seconds.)

INJECTION NOZZLES
UNIT VI

NAME _____

TEST

1. Match the terms on the right to the correct definitions.

_____a. Valve in which the end extends into a shank or pin	1.	Orifice
_____b. Small hole	2.	Injector nozzle
_____c. Nozzle, nozzle holder, valve and spring assembly	3.	Pintle
_____d. Valve, body, and spray valve	4.	Nozzle assembly

2. List two functions of the injection nozzle.

   a.

   b.

3. Name four moving parts in the injection nozzle.

   a.

   b.

   c.

   d.

4. Name three common types of nozzle valves.

   a.

   b.

   c.

5. Match the types of nozzles on the right to their characteristics.

_____a. Used for engines with open combustion chambers	1.	Pintle type (outward-opening)
_____b. Produces a hollow spray; used for engines with precombustion chambers or energy cells	2.	Multiple orifice
_____c. Does not dribble fuel; used for engines with precombustion chamber or energy cells	3.	Pintle type (inward-opening)
_____d. Variation of pintle type; holes have a tendency to clog	4.	Hole type

6. Explain the operation of the injection nozzle.

7. Explain how the nozzle opening pressure is adjusted.

8. Demonstrate the ability to remove, service and test an injection nozzle.

   (NOTE: If the above activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

INJECTION NOZZLES
UNIT VI

ANSWERS TO TEST

1. a. 3
   b. 1
   c. 2
   d. 4
2. a. Atomizes the fuel for better combustion
   b. Spreads the fuel spray to fully mix with air
3. a. Valve
   b. Spring
   c. Spindle
   d. Retainer
4. a. Single hole
   b. Multiple orifice
   c. Pintle type, single hole
5. a. 4
   b. 3
   c. 1
   d. 2
6. Explanation should include:
   a. Hydraulically operated by fuel delivered from the injection pump
   b. Spring loaded valve is lifted allowing pressurized fuel to spray out through one or more orifices into combustion chamber
7. Explanation should include--Adjusted by a screw or shims on the valve spring
8. Performance skill evaluated to the satisfaction of the instructor

GOVERNORS
UNIT VII

UNIT OBJECTIVE

After completion of this unit, the student should be able to explain the operation of the governor on load increase and load decrease and explain how a mechanical and hydraulic governor differs. This knowledge will be evidenced by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able-to:

1. Match terms associated with governors to the correct definitions.
2. List three purposes of a governor.
3. Name two basic types of governors using flyweights.
4. Explain how a mechanical governor and hydraulic governor differ.
5. Name two types of mechanical governors.
6. Name two types of hydraulic governors.
7. Match the kinds of governors to their special functions.
8. Match the types of governors to their characteristics.
9. Explain the operation of the governor on load increase.
10. Explain the operation of the governor on load decrease.
11. Identify the positions of flyweights for load increase or decrease.
12. Describe the characteristics of an isochronous governor.

GOVERNORS
UNIT VII

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information sheet.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Schematic of Governors
2. TM 2--Nonisochronous Governor
3. TM 3--Isochronous Governor
4. TM 4--Governor Operation

D. Test

E. Answers to test

II. References:

A. Kates, Edgar J., and Luck, William E. *Diesel and High Compression Gas Engines.* Chicago: American Technical Society, 1974.

B. *Fundamentals of Service: Engines.* Moline, Illinois: Deere and Company, 1972.

C. Toboldt, Bill. *Diesel: Fundamentals, Service, Repair.* South Holland, Illinois: Goodheart-Willcox Company, 1973.

GOVERNORS
UNIT VII

INFORMATION SHEET

I. Terms and definitions

A. Governor--Device that controls engine speed automatically by varying fuel supply

B. Speed drift--Gradual deviation of the governed speed above or below the desired speed

C. Speed droop--Change in governor rotating speed which causes the governor's fuel control rod to move from full-closed to full-open throttle position or vice versa

D. Dead band--Change in speed the engine must make before the governor will make a corrective movement of the throttle

(NOTE: Dead band is sometimes called sensitivity)

E. Hunting--Oscillations in speed due to over-correction by governor

(NOTE: Hunting is sometimes called surging or rolling)

F. Servomotor--Piston moved by fluid under pressure

G. Isochronous--Ability of governor to maintain a steady engine speed at any load

H. Flyweights--Centrifugal ball head moving in a circular path

II. Purposes of a governor

A. Maintains a selected speed

B. Limits the slow and fast speed

C. Shuts down engine when it over-speeds

III. Basic types of governors using flyweights

A. Mechanical

B. Hydraulic

IV. Mechanical and hydraulic governor differences (Transparency 1)

A. Mechanical governors use mechanical linkage to change engine fuel control

B. Hydraulic governors use hydraulic power to change fuel control

INFORMATION SHEET

V. Types of mechanical governors

A. Limiting speed

B. Variable speed

VI. Types of hydraulic governors (Transparencies 2 and 3)

A. Permanent speed droop

(NOTE: Speed droop is applied to prevent hunting.)

B. Temporary speed droop

(NOTE: Speed droop is applied and then withdrawn so governor becomes isochronous.)

VII. Governors and their special functions

A. Variable speed--Maintains any selected engine speed

B. Over-speed--A safety device which shuts down the engine in case it runs too fast

C. Load limiting--Limits the load to prevent overloading the engine at whatever speed it may be running

D. Load control--Adjusts the amount of load applied to engine to suit the speed at which it is set to run

VIII. Characteristics of mechanical and hydraulic governors

A. Mechanical

1. Has large dead bands

2. Power is small

3. Unavoidable speed droop

B. Hydraulic

1. Is not isochronous

2. Speed droop is not convenient to adjust

(NOTE: Speed droop must be applied and then withdrawn to become an isochronous hydraulic governor.)

INFORMATION SHEET

IX. Operation of governor on load increase (Transparency 4)

(NOTE: Engine speed decreases as load increases.)

A. Flyweights rotate slower

B. Speeder spring forces overcome centrifugal force of flyweights

C. Speeder rod moves down to open fuel valve to increase fuel

X. Operation of governor on load decrease (Transparency 4)

(NOTE: Engine speed increases as load decreases.)

A. Flyweights rotate faster

B. Speeder spring force is overcome by centrifugal force of flyweights

C. Speeder rod moves up forcing fuel valve to close

XI. Position of flyweights (Transparency 4)

A. Load increase--Flyweights move in

B. Load decrease--Flyweights move out

XII. Characteristics of an isochronous governor

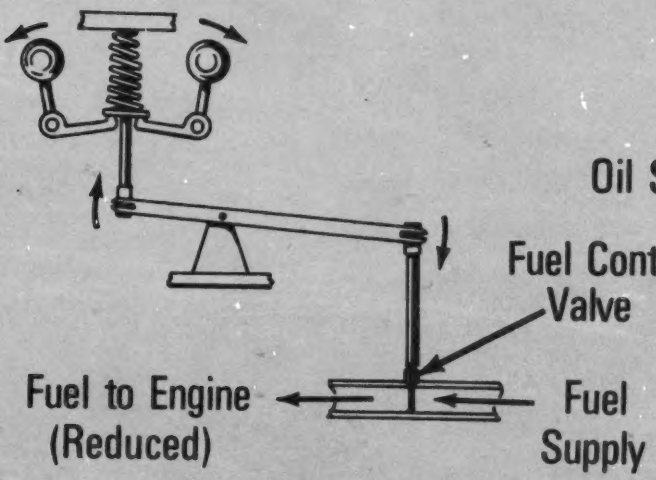
A. Maintains constant speed without hunting

B. Speed droop is temporary

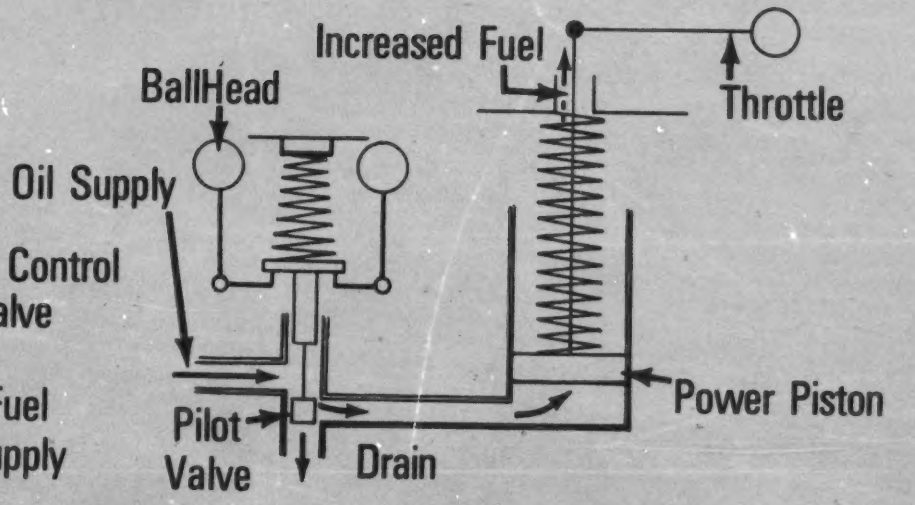
(NOTE: Speed droop employed to give stability while fuel is being corrected and speed droop is removed as engine responds to fuel change.)

Schematic of Governors

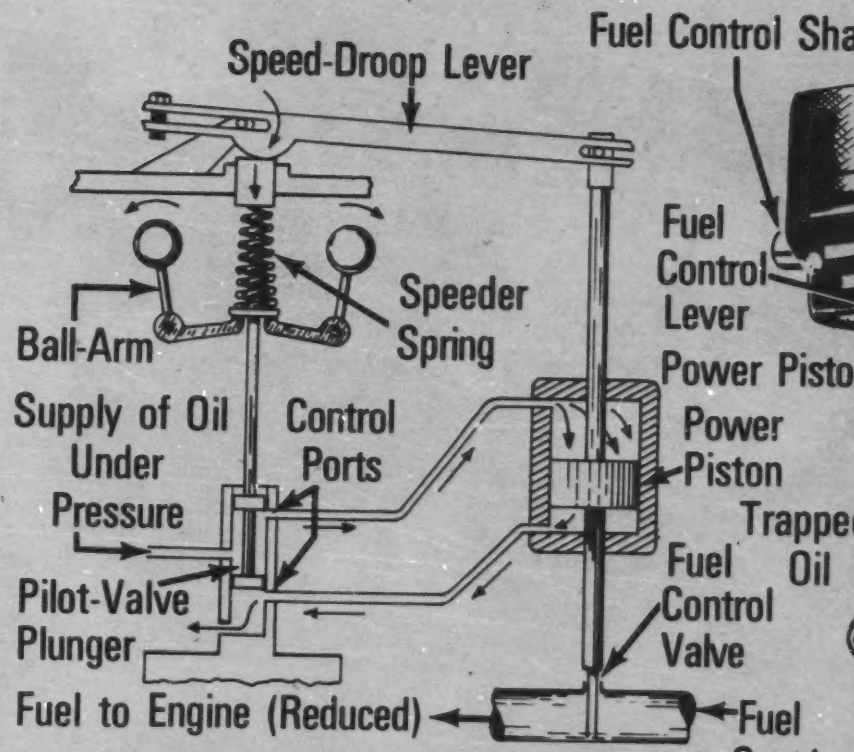
Load Decrease on Mechanical Governor



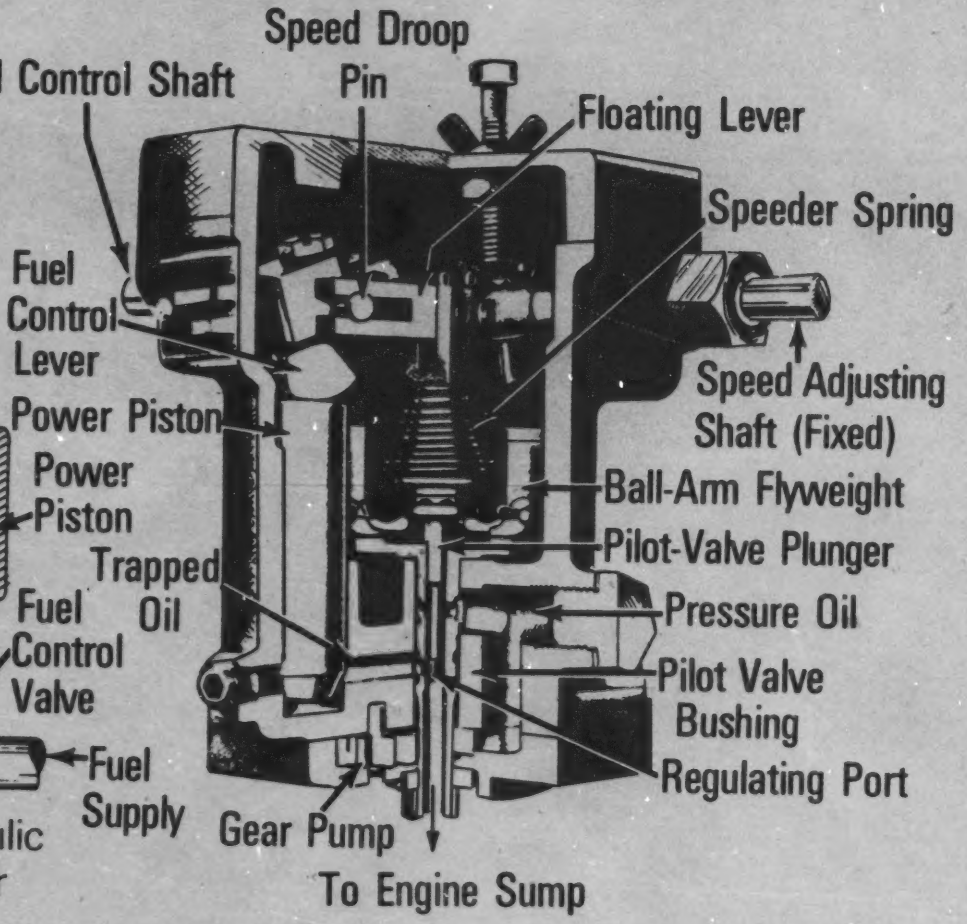
Hydraulic Governor (Diesel)



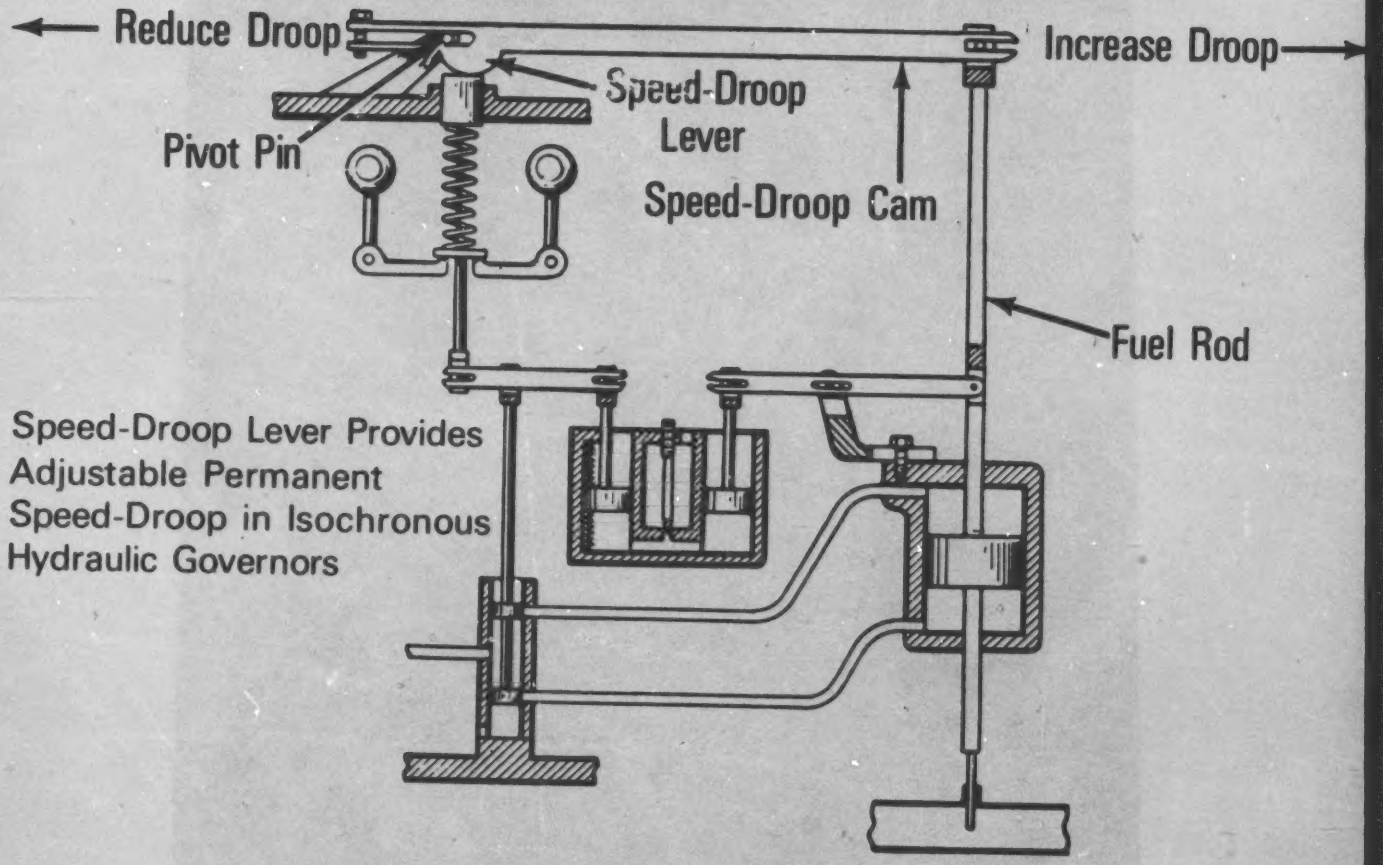
Nonisochronous Governor



Effect of Load Decrease on Hydraulic Governor With Speed-Droop Lever

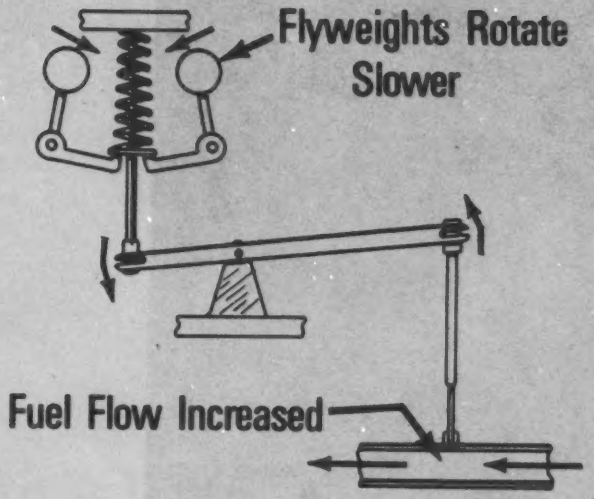


Isochronous Governor



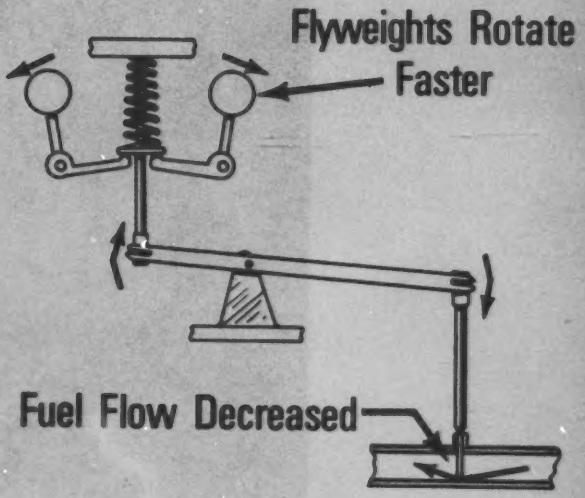
Governor Operation

Load Increases,
Engine Speed Decreases



Increased Load

Load Decreases,
Engine Speed Increases



Decreased Load

Operation of Centrifugal Governor

GOVERNORS
UNIT VII

NAME _____

TEST

1. Match the terms on the right to the correct definitions.

_____a.	Device that controls engine speed automatically by varying fuel sypply	1. Speed drift
_____b.	Gradual deviation of the governed speed above or below the desired speed	2. Governor
_____c.	Change in governor rotating speed which causes the governor's fuel control rod to move from full-closed to full-open throttle position or vice versa	3. Isochronous
_____d.	Change in speed the engine must make before the governor will make a corrective movement of the throttle	4. Hunting
_____e.	Oscillations in speed due to over-correction by governor	5. Servomotor
_____f.	Piston moved by fluid under pressure	6. Dead band
_____g.	Ability of governor to maintain a steady engine speed at any load	7. Speed droop
_____h.	Centrifugal ball head moving in a circular path	8. Flyweights

2. List three purposes of a governor.

a.

b.

c.

3. Name two basic types of governors using flyweights.

a.

b.

4. Explain how a mechanical governor and a hydraulic governor differ.

5. Name two types of mechanical governors.

   a.

   b.

6. Name two types of hydraulic governors.

   a.

   b.

7. Match the kinds of governors on the right to their special functions.

_____a.	Maintains any selected engine speed	1.	Over-speed
_____b.	A safety device which shuts down the engine in case it runs too fast	2.	Load control
		3.	Load limiting
_____c.	Limits the load to prevent overloading the engine at whatever speed it may be running	4.	Variable speed
_____d.	Adjusts the amount of load applied to engine to suit the speed at which it is set to run		

8. Match the types of governors to their characteristics.

_____a.	Has large dead bands	1.	Mechanical
_____b.	Speed droop is not convenient to adjust	2.	Hydraulic
_____c.	Unavoidable speed droop		
_____d.	Is not isochronous		
_____e.	Power is small		

9. Explain the operation of the governor on load increase.

10. Explain the operation of the governor on load decrease.

11. Identify the position of flyweights for load increase of load decreases by writing figure 1 or figure 2 in the appropriate blanks.

_____a. Load increase

_____b. Load decrease

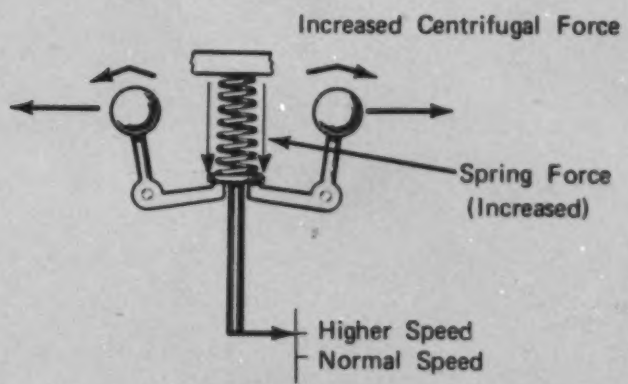


FIGURE 1

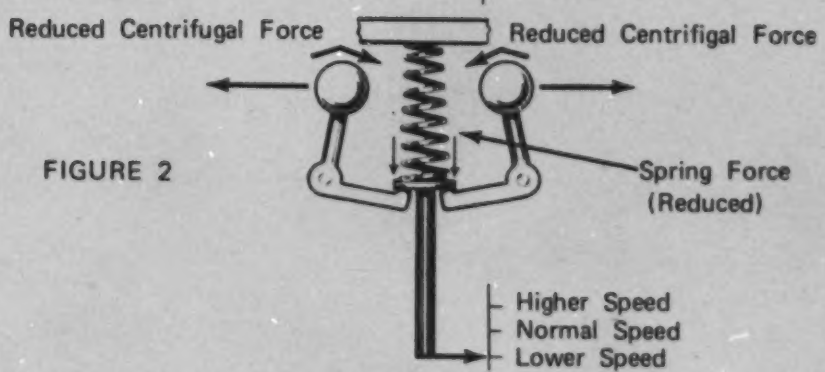


FIGURE 2

12. Describe the characteristics of an isochronous governor.

GOVERNORS
UNIT VII

ANSWERS TO TEST

1. a. 2
   b. 1
   c. 7
   d. 6
   e. 4
   f. 5
   g. 3
   h. 8
2. a. Maintains a selected speed
   b. Limits the slow and fast speed
   c. Shuts down engine when it over-speeds
3. a. Mechanical
   b. Hydraulic
4. Explanation should include:
   a. Mechanical governors use mechanical linkage to change engine fuel control
   b. Hydraulic governors use hydraulic power to change fuel control
5. a. Limiting speed
   b. Variable speed
6. a. Permanent speed droop
   b. Temporary speed droop
7. a. 4
   b. 1
   c. 3
   d. 2
8. a. 1
   b. 2
   c. 1
   d. 2
   e. 1

9. Explanation should include:
   a. Flyweights rotate slower
   b. Speeder spring forces overcome centrifugal force of flyweights
   c. Speeder rod moves down to open fuel valve to increase fuel
10. Explanation should include:
   a. Flyweights rotate faster
   b. Speeder spring force is overcome by centrifugal force of flyweights
   c. Speeder rod moves up forcing fuel valve to close
11. a. Figure 2
   b. Figure 1
12. Description should include:
   a. Maintains constant speed without hunting
   b. Speed droop is temporary

PRINCIPLES OF ELECTRICITY
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to define electricity according to the electron theory and apply ohm's law to measure voltage, amperes, and resistance in a basic circuit. The student should be able to identify three types of electrical circuits and distinguish between the characteristics of alternating and direct current. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with electricity to the correct definitions.
2. Name two particles found in an atom.
3. Explain the nature of electron flow.
4. Define electricity according to the atomic theory.
5. Identify three sources of electricity related to diesel engines.
6. Name three parts of a basic circuit.
7. Distinguish between a good conductor and a good insulator in electron theory.
8. Distinguish between good conductors and insulators of electricity.
9. Explain why copper is widely used as a conductor.
10. Match the basic circuit terms to their units of measure.
11. List two causes of resistance to the flow of current (electrons).
12. Match the basic electrical schematic symbols to the correct names.
13. Match the letter designations used in ohm's law to the correct terms.
14. Draw ohm's law formula in triangle expression.
15. State ohm's law in letter formula for calculating voltage, current, and resistance.
16. Identify three types of electrical circuits.

17. List three rules for series circuits.

18. List three rules for parallel circuits.

19. Name three factors affecting resistance in a conductor.

20. Select the characteristics of magnetism.

21. Explain two ways an iron bar may be magnetized.

22. Discuss the relationship between electricity and magnetism.

23. Discuss the principle of electromagnetic induction.

24. List three ways in which a voltage can be induced by electromagnetic induction.

25. List three factors that determine the magnitude of induced voltage.

26. Name two types of electric current.

27. Distinguish between direct and alternating current.

28. Name four instruments used in checking electrical circuits.

29. Solve problems using ohm's law formula.

PRINCIPLES OF ELECTRICITY
UNIT I

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information and assignment sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information and assignment sheets.

F. Demonstrate magnetic lines of force by using iron filings and a conductor.

G. Assign students to construct a series and a parallel circuit.

H. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete assignment sheet.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Structure of Atoms
2. TM 2--Electron Flow
3. TM 3--Sources of Electricity
4. TM 4--Ohm's Law in Triangle Expression

5. TM 5--Ohm's Law in Letter Designation
6. TM 6--Types of Electrical Circuits
7. TM 7--Series Circuit Rules
8. TM 8--Parallel Circuit Rules
9. TM 9--Magnetism and Field of Force
10. TM 10--Electricity and Magnetism Relationship
11. TM 11--Measuring Instruments

D. Assignment Sheet #1--Solve Problems Using Ohm's Law

E. Answers to assignment sheet

G. Test

H. Answers to test

II. References:

A. *Fundamentals of Service: Electricity.* Moline, Illinois: Deere and Company, 1972.

B. Parady, Harold W., and Turner, J. Howard. *Electric Energy.* Athens, Georgia: American Association for Vocational Instructional Materials, 1976.

PRINCIPLES OF ELECTRICITY
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Atom--Smallest unit of all matter

B. Electrons--Particles with a negative charge in orbit around a core of protons

C. Protons--Particles with a positive charge that make up the nucleus of the atom

D. Current--Flow of electrons through a conductor, measured in amperes

E. Conductor--Any material that permits passage of electric current

F. Semiconductor--An element which has four electrons in outer ring; used to make diodes and transistors, not a good conductor or insulator

G. Voltage--Potential difference that causes flow of current

H. Resistance--Opposition to current flow in a conductor

I. Insulator--Material with an extremely high resistance to current flow

J. Electrochemical--Stored chemical energy which can be converted to electrical current

K. Electromagnetic--Electricity generated by cutting the magnetic lines of force (field) around a magnet

L. Thermoelectric--Electricity generated by heat

M. Thermocouple--Thermoelectric device used to measure temperature accurately

N. Electromagnetic induction--Inducing voltage in a conductor that moves across a magnetic field

O. Mutual induction--Occurs when changing current in one coil induces voltage in a second coil

P. Self induction--Voltage which occurs in a coil when there is a change of current

Q. Generator (direct current)--Voltage and current produced by moving conductors across a stationary magnetic field

INFORMATION SHEET

R. Alternator (alternating current generator)--Voltage and current produced by a rotating magnetic field cutting across stationary conductors

S. Work--Force times distance

T. Power--Rate of doing work

U. Watt--Electrical measurement of rate of doing work

(NOTE: 746 watts = 1 horsepower.)

V. Emf--Electromotive force or voltage

W. Counter emf--Voltage induced in a conductor which is moving through a magnetic field in opposition to the source of voltage

(NOTE: This is a generator action developed in every motor.)

X. Cycle (hertz)--One complete reversal of an alternating current from positive to negative and back to the starting point

Y. Parallel circuit--Current has more than one path to take

Z. Series circuit--Current has only one path it can take

AA. Series-parallel circuit--A circuit consisting of both series and parallel components

II. Particles in an atom (Transparency 1)

A. Electron

B. Proton

(NOTE: These are the particles involved in the electron theory.)

III. Nature of electron flow--When acted upon by a source such as friction, electrons in the outer ring or orbit break away to other atoms (Transparency 2)

Example: When a rubber rod is rubbed with wool, electrons are removed from the wool and collected on the rod. The wool now has too few electrons and is positively charged. The rod has too many electrons and is negatively charged.

IV. Electricity--The flow of electrons from atom to atom in a conductor (Transparency 2)

INFORMATION SHEET

V. Sources of electricity related to diesel engines (Transparency 3)

- A. Thermoelectric
- B. Electrochemical
- C. Electromagnetic

VI. Parts of a circuit

- A. Voltage
  - Example: Battery
- B. Resistor
  - Example: Light bulb
- C. Conductor
  - Example: Copper wire

VII. Conductor and insulator difference

- A. Conductor has less than four electrons in outer ring
- B. Insulator has more than four electrons in outer ring

VIII. Conductors and insulators of electricity

- A. Conductors
  1. Silver
     (NOTE: Silver has the least resistance to current flow.)
  2. Copper
  3. Gold
  4. Aluminum
  5. Tungsten
  6. Zinc
  7. Brass
  8. Platinum
  9. Iron
  10. Nickel

INFORMATION SHEET

11. Tin
12. Steel
13. Lead
14. Mercury
15. Nichrome

(NOTE: Nichrome has the highest resistance to current flow.)

B. Insulators

1. Glass
2. Rubber
3. Plastic
4. Wood
5. Ceramic
6. Mica

IX. Copper as a conductor--Copper has only one electron in outer ring and is comparitively cheaper than other metals which may have the same properties (Transparency 1)

X. Circuit terms and unit of measure

A. Current--Amperes

B. Voltage--Volts

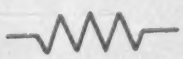
C. Resistance--Ohms

XI. Causes of resistance

A. Core of atoms (protons) attracts orbiting electrons, which resist their removal

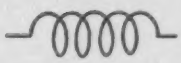
B. Collision of countless electrons as they move

XII. Basic electrical schematic symbols

A. Resistance or load 

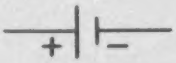
INFORMATION SHEET

B. Ohm's of resistance

C. Inductor (coil) 

D. Inductor (solenoid)

E. Ground

F. Battery 

G. Connection

H. Terminal

I. Switch (open)

J. Circuit breaker

K. Crossover

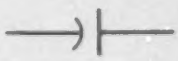
L. Direction of current

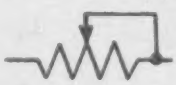
M. Diode (one-way)

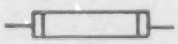
N. Zener diode

O. Transistor (PNP type)

P. Transistor (NPN type)

Q. Capacitor 

R. Variable resistor 

S. Fuse 

INFORMATION SHEET

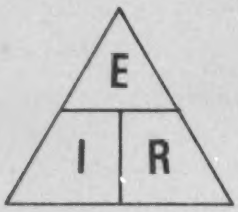
XIII. Letters and terms

A. E--Electromotive force in volts

B. I--Intensity (current) in amps

C. R--Resistance in ohms

XIV. Ohm's law formula in triangle expression (Transparency 4)



(NOTE: E.I.R. formula reminder is the phrase "Even I Remember.")

XV. Ohm's law in letter formula (Transparency 5)

A. E = I x R or Volts = Amps x Ohms

B. I = E/R or Amps = Volts ÷ Ohms

C. R = E/I or Ohms = Volts ÷ Amps

XVI. Types of electrical circuits (Transparency 6)

A. Series

B. Parallel

C. Series-parallel

XVII. Rules for series circuits (Transparency 7)

A. Current through each resister is the same

B. Voltage drops across each resistor will be different if the resistance values are different

C. Sum of the voltage drops equals the source voltage

XVIII. Rules for parallel circuit (Transparency 8)

A. Voltage across each resistor is the same

B. Current through each resistor will be different if the resistance values are different

C. Sum of the separate currents equals the total circuit current

INFORMATION SHEET

XIX. Factors affecting resistance in a conductor

A. Length of wire

B. Diameter of wire

C. Temperature of wire

XX. Characteristics of magnetism (Transparency 9)

A. Every magnet has a north and south pole

B. Unlike poles attract and like poles repel

C. Every magnet has a field of force surrounding it

D. Magnetic materials are acted upon when located in a field of force

E. An unmagnetized piece of iron can become a magnet through the principle of electromagnetic induction

XXI. Magnetizing an iron bar

A. Stroke an iron bar with another bar which has been magnetized

B. Place an iron bar in a strong magnetic field

(NOTE: Soft metals will not retain much magnetism when withdrawn from the magnetic field.)

XXII. Relationship between electricity and magnetism (Transparency 10)

A. Current passed thorugh a wire (conductor) creates a magnetic field around the wire

B. Magnetic lines have direction and change direction when the current flow changes from one direction to another

(NOTE: The Right Hand Rule for a straight conductor can be used to find the direction of the lines of force around the wire. To apply the rule, grasp the wire with the thumb extended in the direction of conventional current flow (positive to negative); the fingers will then point in the direction in which the lines of force surround the conductor. These lines of force are always at right angles to the conductor.)

C. Two conductors on an armature, carrying current in opposite directions, create a strong and weak field on opposite sides causing conductors to move apart or armature to rotate

(NOTE: The downward movement or rotation is caused by current flowing in the conductor. This is the principle by which a cranking motor operates.)

INFORMATION SHEET

XXIII. Electromagnetic induction

A. Conductor moving across a magnetic field will have a voltage (emf) induced in it

B. Voltage polarity and the current flow direction are determined by the direction of wire movement and direction of the lines of force

(NOTE: The conductor can move or the magnetic field can move.)

XXIV. Ways to induce a voltage by electromagnetic induction

A. Generated voltage by relative motion

Examples: Generators and alternators

B. Self induction voltage created by a change of current in the conductor

Example: Primary of ignition coils

C. Mutual induction voltage which occurs when changing current in one coil induces voltage in a second coil

Example: Two windings of ignition coils

XXV. Factors that determine the magnitude of induced voltage

A. Strength of the magnetic field

B. Speed at which lines of force are cutting across the conductor

C. Number of conductors that are cutting across the lines of force

XXVI. Types of electric current

A. Direct

B. Alternating

XXVII. Direct and alternating current

A. Direct current

1. Supplied by

a. Generator

b. Battery

1) Dry cell

2) Wet cell

INFORMATION SHEET

2. Flows in one direction only

3. Abbreviated as DC

B. Alternating current

1. Supplied by an alternating current generator (alternator)

2. Flows in one direction then reverses and flows in the opposite direction

3. Abbreviated as AC

XXVIII. Instruments used in checking electrical circuits (Transparency 11)

A. Ammeter

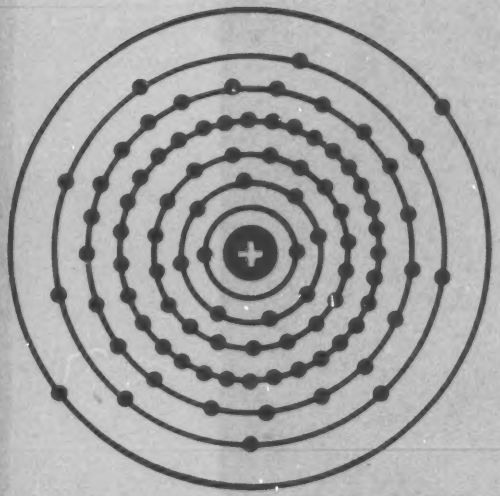
B. Voltmeter

C. Ohmmeter

D. Wattmeter

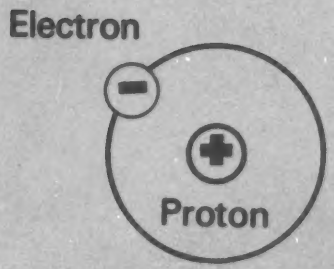
(NOTE: Modern testers often combine the voltmeter, ammeter, and ohmmeter in one test unit, such as a battery-starter tester.)

Structure of Atoms



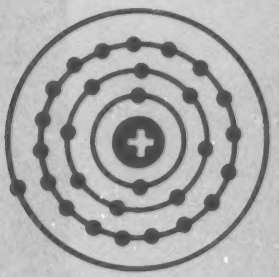
Uranium Atom

92 Electrons
92 Protons



Hydrogen Atom

1 Electron
1 Proton

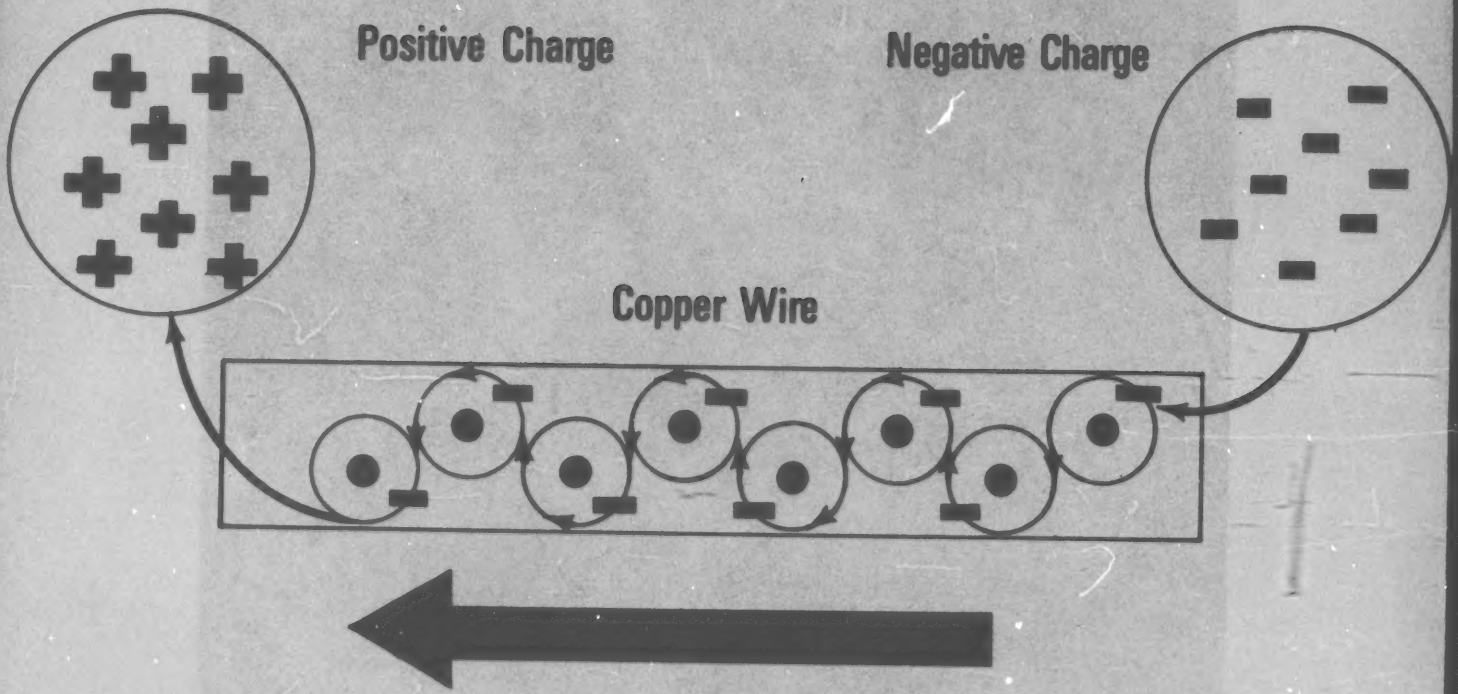


Copper Atom

29 Electrons
29 Protons

NOTE: Count the Number of Electrons in the Outer Ring of the Atom.

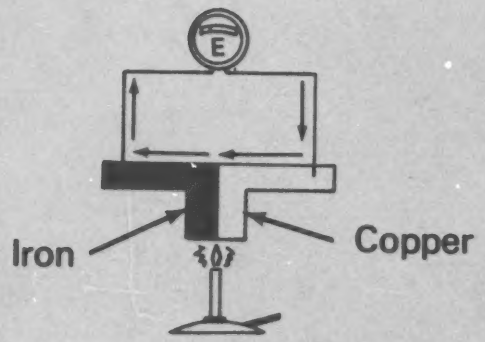
Electron Flow



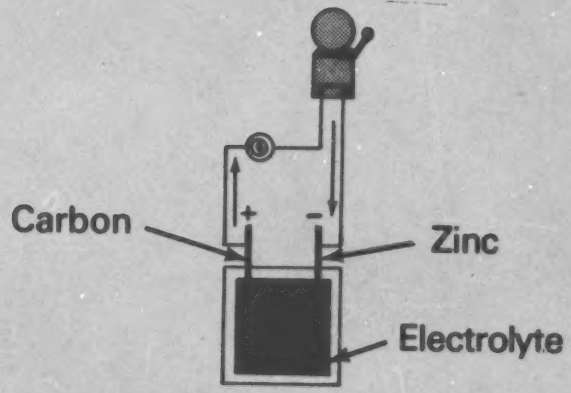
Electron Flow

848

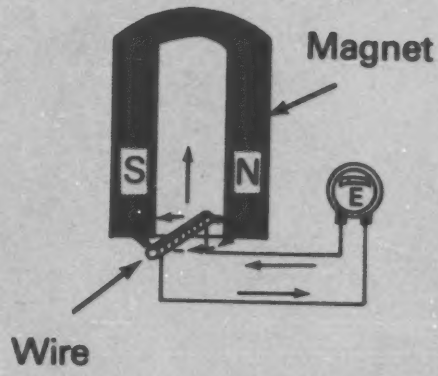
Sources of Electricity



Thermocouple



Battery



Generator

Thermoelectric Source

Electrochemical Source

Electromagnetic Source

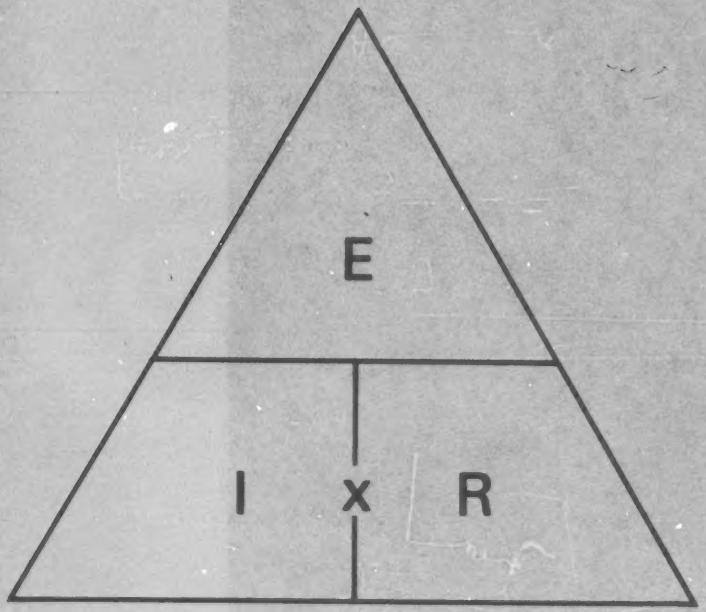
TM 3

849

850

D - 19-F

Ohm's Law in Triangle Expression



NOTE: Solve for Volts, Amps, or Resistance by Covering the Unknown

Example: Cover E, then E = I x R
Cover I, then I = E ÷ R
Cover R, then R = E ÷ I

E = Volts I = Amps R = Resistance

Ohm's Law in Letter Designation

Electromotive Force = Current x Resistance

$E = IR$ Volts = Amperes x Ohms

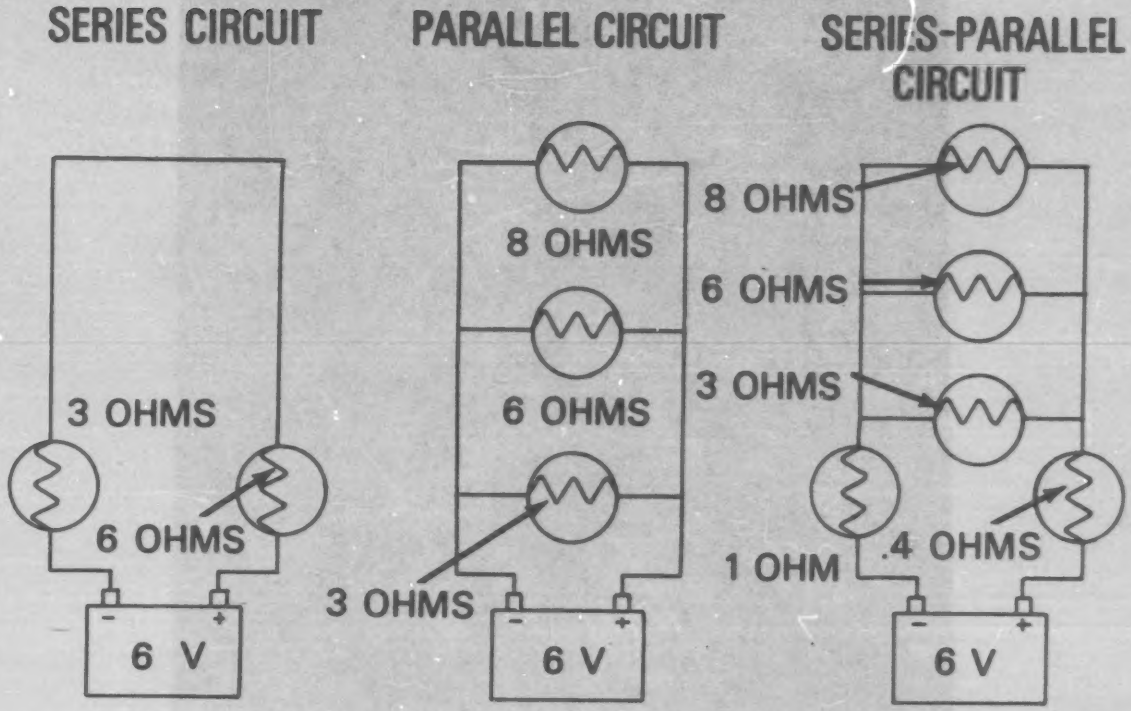
Current = $\frac{\text{Electromotive Force}}{\text{Resistance}}$

$I = \frac{E}{R}$ Amperes = $\frac{\text{Volts}}{\text{Ohms}}$

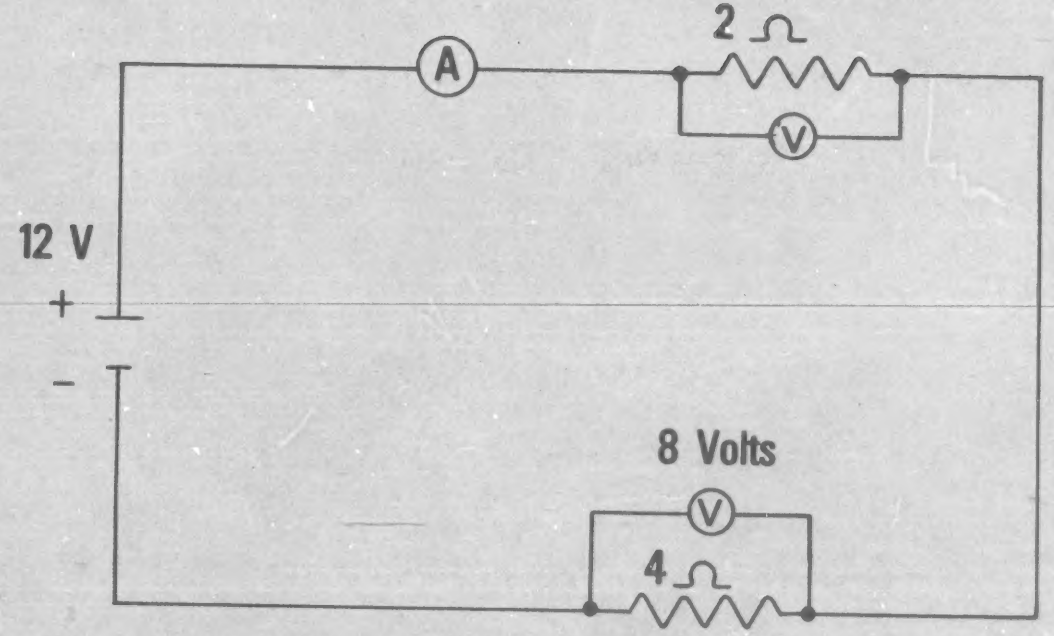
Resistance = $\frac{\text{Electromotive Force}}{\text{Current}}$

$R = \frac{E}{I}$ Ohms = $\frac{\text{Volts}}{\text{Amperes}}$

Types Of Electrical Circuits



Series Circuit Rules

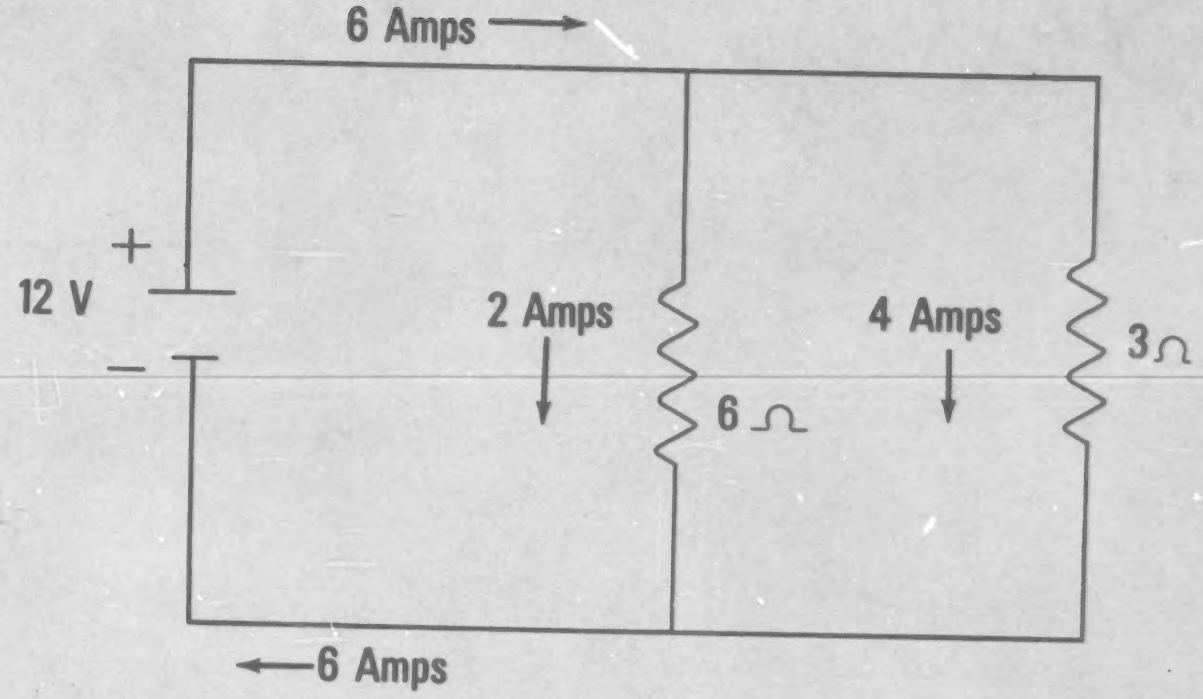


A. I = E/R·I
= 12/6 = 2 Amperes

B. E = IR
E = 2×2 = 4 Volts
E = 2×4 = 8 Volts

C. 4+8 =12 Volts

Parallel Circuit Rules

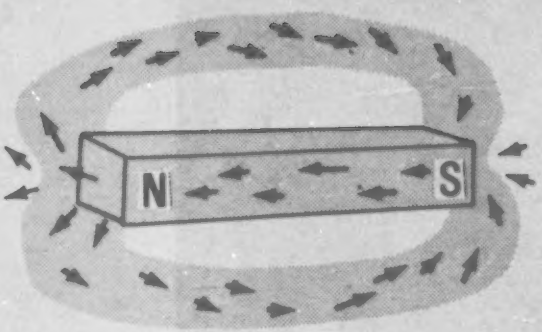


A. Battery voltage across each resistor = 12 Volts

B. I = E/R = 12/6
= 2 Amperes
I = E/R = 12/3
= 4 Amperes

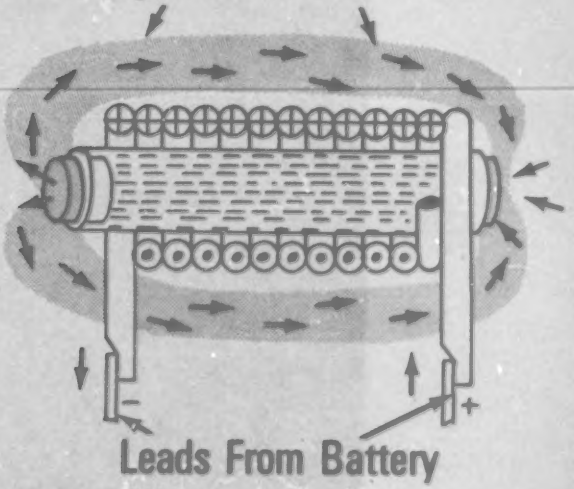
C. I = 6 Amps R = E/I
= 12/6 = 2 Ohms

Magnetism And Field Of Force

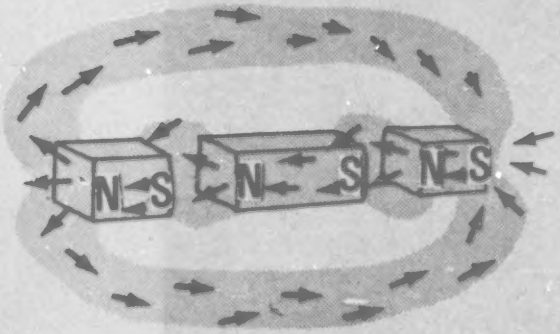


Unmagnetized Iron Filings

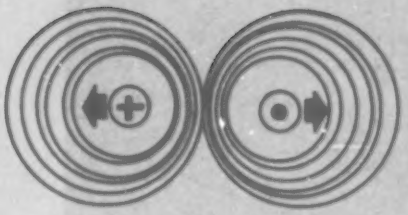
Magnetic Lines of Force



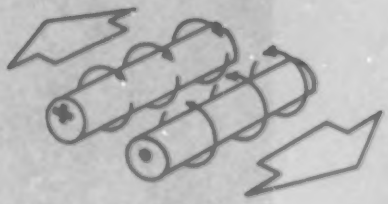
Leads From Battery



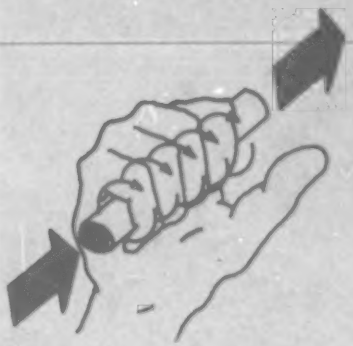
Electricity And Magnetism Relationship



Strong Field Between Conductors



Conductors Tend To Move Apart



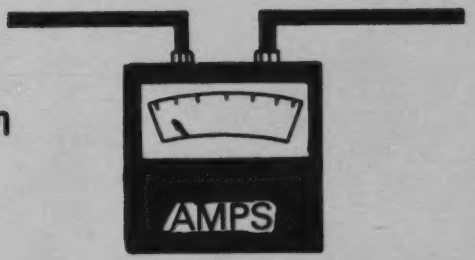
Right Hand Rule For Straight Conductor

Arrows Show Direction Of Field Of Force

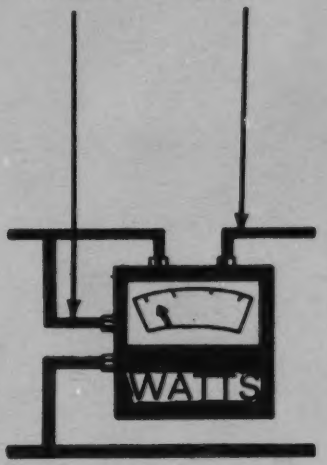
Motor Principle

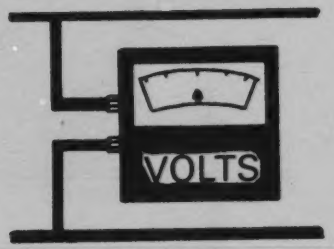
Measuring Instruments

Electric current is measured in amperes with an ammeter.

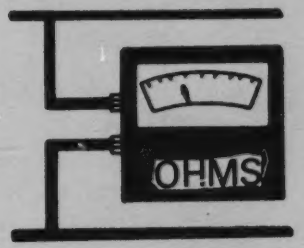


Volts x Amps





Electric "pressure" is measured in volts with a voltmeter.



Resistance is measured in ohms with a ohmmeter.

Electric power is measured in watts with a wattmeter.

PRINCIPLES OF ELECTRICITY
UNIT I

ASSIGNMENT SHEET #1--SOLVE PROBLEMS USING OHM'S LAW

Read the problems and use the triangle expression of ohm's law to solve for the unknown value in each problem.

Example: Cover the unknown in the triangle and solve

(NOTE: E = Voltage; I = Amperes; R = Resistance.)

Show your work on each problem. Turn in to instructor after completion.

1. A current of 4 amperes is needed to operate a certain light bulb having a resistance of 3 ohms. What voltage is required?

2. Through how many ohms resistance does 12 volts force a current of 12 amperes?

3. An electric horn requires 12 volts; the resistance is 20 ohms. What current does the horn take?

(NOTE: The electrical energy consumed in any resistance appears as heat. There is a definite relation between the power consumed and the heat produced. This is in accordance with the principle that energy cannot be destroyed.)

ASSIGNMENT SHEET #1

4. A light bulb having a resistance of 6 ohms, uses 2 amperes of current while in operation. What is the voltage applied to the circuit?

5. A horn connected to a 12 volt battery uses 2 amperes of current for its operation. What is the resistance of the horn?

PRINCIPLES OF ELECTRICITY
UNIT I

ANSWERS TO ASSIGNMENT SHEET

1. Covering up the E shows the formula for this problem to be I x R. Therefore, E = IR = 4 x 3 = 12 volts.

2. Covering up the R shows that R = E/I which equals 12/12 = 1 ohm.

3. Covering up the I shows that I = E/R. Therefore, 12/20 = .6 amperes.

4. E = I x R. Therefore 6 x 2 = 12 volts.

5. R = E/I. Therefore, 12/2 = 6 ohms.

PRINCIPLES OF ELECTRICITY
UNIT I

NAME_____

TEST

1. Match the terms on the right to the correct definitions.

_____a. Smallest unit of all matter

_____b. Particles with a negative charge in orbit around a core of protons

_____c. Particles with a positive charge that make up the nucleus of the atom

_____d. Flow of electrons through a conductor, measured in amperes

_____e. Any material that permits passage of electric current

_____f. An element which has four electrons in outer ring; used to make diodes and transitors; not a good conductor or insulator

_____g. Potential difference that causes flow of current

_____h. Opposition to current flow in a conductor

_____i. Material with an extremely high resistance to current flow

_____j. Stored chemical energy which can be converted to electrical current

_____k. Electricity generated by cutting the magnetic lines of force (field) around a magnet

_____l. Electricity generated by heat

_____m. Thermoelectric device used to measure temperature accurately

_____n. Inducing voltage in a conductor that moves across a magnetic field

_____o. Occurs when changing current in one coil induces voltage in a second coil

1. Resistance
2. Thermoelectric
3. Electrochemical
4. Electromagnetic
5. Electromagnetic induction
6. Electrons
7. Atom
8. Current
9. Generator (direct current)
10. Alternator (alternating current generator)
11. Voltage
12. Protons
13. Watt
14. Power

_____p. Voltage which occurs in a coil when there is a change of current

_____q. Voltage and current produced by moving conductors across a stationary magnetic field

_____r. Voltage and current produced by a rotating magnetic field cutting across stationary conductors

_____s. Force times distance

_____t. Rate of doing work

_____u. Electrical measurement of rate of doing work

_____v. Electromotive force or voltage

_____w. Voltage induced in a conductor which is moving through a magnetic field in opposition to the source of voltage

_____x. One complete reversal of an alternating current from positive to negative and back to the starting point

_____y. Current has more than one path to take

_____z. Current has only one path it can take

____aa. A circuit consisting of both series and parallel components

15. Work
16. Thermocouple
17. Emf
18. Cycle (hertz)
19. Series-parallel circuit
20. Conductor
21. Series circuit
22. Insulator
23. Counter emf
24. Parallel circuit
25. Semiconductor
26. Mutual induction
27. Self induction

2. Name two particles found in an atom.

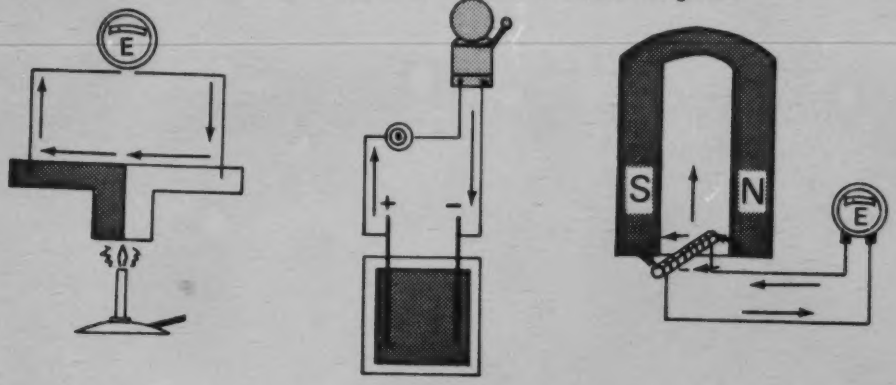
a.

b.

3. Explain the nature of electron flow.

4. Define electricity according to the atomic theory.

5. Identify three sources of electricity related to diesel engines.



a. _____ b. _____ c. _____

6. Name three parts of a basic circuit.

a.

b.

c.

7. Distinguish between a good conductor and a good insulator in electron theory by placing an "X" next to the description of an insulator.

_____a. Has more than four electrons in outer ring

_____b. Has less than four electrons in outer ring

8. Distinguish between good conductors and insulators by placing a "c" in front of the items that are good conductors and an "i" in front of the insulators.

_____a. Mercury

_____b. Brass

_____c. Rubber

_____d. Glass

_____e. Wood

_____f. Nickel

_____g. Plastic

_____h. Nichrome

_____i. Silver

_____j. Gold

_____k. Ceramic

_____l. Aluminum

9. Explain why copper is widely used as an conductor.

10. Match the basic circuit terms on the right to their units of measure.

_____a. Volts	1. Current
_____b. Ohms	2. Voltage
_____c. Amperes	3. Resistance

11. List two causes of resistance to the flow of current (electrons).

a.

b.

12. Match the basic electrical schematic symbols to the correct names.

_____a. Resistance or load

_____b. Ohm's of resistance

_____c. Inductor (coil)

_____d. Inductor (solenoid)

_____e. Ground

_____f. Battery

_____g. Connection

_____h. Terminal

_____i. Switch (open)

_____j. Circuit breaker

_____k. Crossover

_____l. Direction of current

_____m. Diode (one-way)

_____n. Zener diode

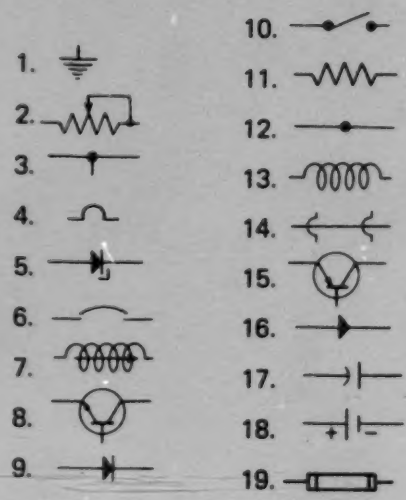
_____o. Transistor (PNP type)

_____p. Transistor (NPN type)

_____q. Capacitor

_____r. Variable resistor

_____s. Fuse



13. Match letter designations used in ohm's law to the correct terms.

_____	a. Electromotive force in volts	1.	R
_____	b. Intensity (current) in amps	2.	I
_____	c. Resistance in ohms	3.	E

14. Draw ohm's law formula in triangle expression.

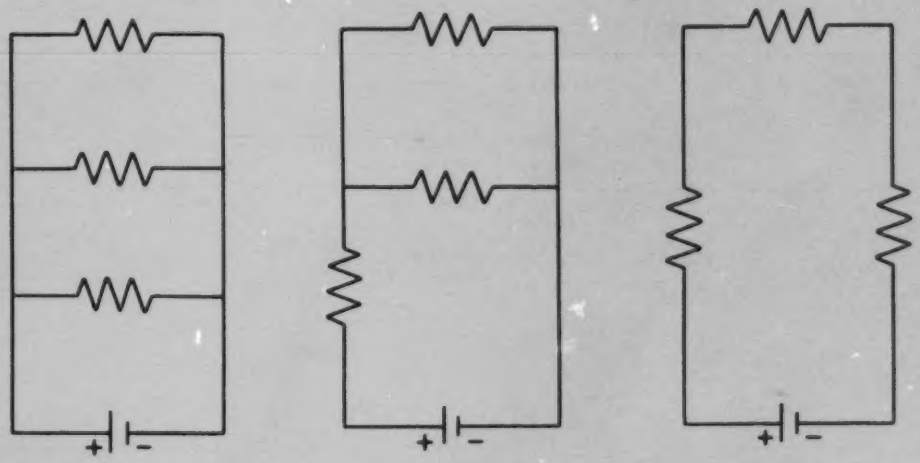
15. State ohm's law in letter formula for calculating voltage, current, and resistance.

a.

b.

c.

16. Identify three types of electrical circuits.



a. _____ b. _____ c. _____

17. List three rules for series circuits.

a.

b.

c.

18. List three rules for parallel circuits.

a.

b.

c.

19. Name three factors affecting resistance in a conductor.

a.

b.

c.

20. Select the characteristics of magnetism by placing an "X" in the appropriate blanks.

_____a. Every magnet has a north and south pole

_____b. Like poles attract and unlike poles repel

_____c. Magnetic materials are acted upon when located in a field of force

_____d. Every magnet has a field of force surrounding it

_____e. Unlike poles attract and like poles repel

21. Explain two ways an iron bar may be magnetized.

a.

b.

22. Discuss the relationship between electricity and magnetism.

23. Discuss the principle of electromagnetic induction.

24. List three ways in which voltage may be induced by electromagnetic induction.

a.

b.

c.

25. List three factors that determine the magnitude of induced voltage.

a.

b.

c.

26. Name two types of electric current.

a.

b.

27. Distinguish between direct and alternating current by placing "AC" in front of the items that refer to alternating current and "DC" is front of the items that refer to direct current.

_____a. Flows in one direction then reverses and flows in the opposite direction

_____b. Dry cell battery

_____c. Supplied by an alternating current generator (alternator)

_____d. Flows in one direction only

_____e. Supplied by a generator

28. Name four instruments used in checking electrical circuits.

a.

b.

c.

d.

29. Solve the following problems using ohm's law formula.

a. A current of 1.5 amperes is needed to operate a certain light bulb having a resistance of 8 ohms. What voltage is required?

b. A horn connected to a 12 volt battery uses 4 amperes of current for its operation. What is the resistance of the horn?

PRINCIPLES OF ELECTRICITY
UNIT I

ANSWERS TO TEST

1.

a.	7	h.	1	o.	26	v.	17
b.	6	i.	22	p.	27	w.	23
c.	12	j.	3	q.	9	x.	18
d.	8	k.	4	r.	10	y.	24
e.	20	l.	2	s.	15	z.	21
f.	25	m.	16	t.	14	aa.	19
g.	11	n.	5	u.	13		

2. a. Electron

   b. Proton

3. When acted upon by a source such as friction, electrons in the outer ring or orbit break away to other atoms

4. The flow of electrons from atom to atom in a conductor

5. a. Thermoelectric

   b. Electrochemical

   c. Electromagnetic

6. a. Voltage

   b. Resistor

   c. Conductor

7. a

8.

a.	c	g.	i
b.	c	h.	c
c.	i	i.	c
d.	i	j.	c
e.	i	k.	i
f.	c	l.	c

9. Copper has only one electron in outer ring and is comparitively cheaper than other metals which may have the same properties

10. a. 2

    b. 3

    c. 1

11. a. Core of atoms (protons) attracts orbiting electrons, which resist their removal

    b. Collision of countless electrons as they move

12.

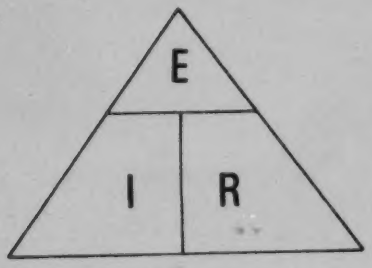
a.	11	f.	18	k.	14	p.	8
b.	4	g.	3	l.	16	q.	17
c.	13	h.	12	m.	9	r.	2
d.	7	i.	10	n.	5	s.	19
e.	1	j.	6	o.	15		

13. a. 3

    b. 2

    c. 1

14.



15. a. $E = I \times R$

    b. $I = E/R$

    c. $R = E/I$

16. a. Parallel

    b. Series-parallel

    c. Series

17. a. Current through each resistor is the same

    b. Voltage drops across each resistor will be different if the resistance values are different

    c. Sum of the voltage drops equals the source voltage

18. a. Voltage across each resistor is the same

    b. Current through each resistor will be different if the resistance values are different

    c. Sum of the separate currents equals the total circuit current

19. a. Length of wire

    b. Diameter of wire

    c. Temperature of wire

20. a, c, d, e

21. Explanation should include:

    a. Stroke an iron bar with another bar which has been magnetized

    b. Place an iron bar in a strong magnetic field

22. Discussion should include:

    a. Current passed through a wire (conductor) creates a magnetic field around the wire

    b. Magnetic lines have direction and change direction when the current flow changes from one direction to another

    c. Two conductors on an armature, carrying current in opposite directions, create a strong and weak field on opposite sides, causing conductors to move apart or armature to rotate

23. Discussion should include:

    a. Conductor moving across a magnetic field will have the voltage (emf) induced in it

    b. Voltage polarity and the current flow direction are determined by the direction of wire movement and direction of lines of force

24. a. Generated voltage by relative motion

    b. Self induction voltage created by a change of current in the conductor

    c. Mutual induction voltage which occurs when changing current in one coil induces voltage in a second coil

25. a. Strength of the magnetic field
    b. Speed at which lines of force are cutting across the conductor
    c. Number of conductors that are cutting across the lines of force
26. a. Direct
    b. Alternating
27. a. AC
    b. DC
    c. AC
    d. DC
    e. DC
28. a. Ammeter
    b. Voltmeter
    c. Ohmmeter
    d. Wattmeter
29. a. 12 volts
    b. 3 ohms

STORAGE BATTERIES
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to list the functions of a battery and discuss the process by which it converts chemical energy into electrical energy. The student should also be able to select safety rules, explain the term "battery rating", and demonstrate the ability to service and load test a battery. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with storage batteries to the correct definitions.
2. List three functions of the battery.
3. Match the parts of the battery to their purposes.
4. Discuss the process by which a battery converts chemical energy into electrical energy during the discharging and charging cycle.
5. Explain the term battery rating.
6. Select safety rules to be observed during the care and maintenance of batteries.
7. Name three characteristics of "service free" batteries.
8. Demonstrate the ability to:
   a. Clean and service a battery.
   b. Remove and replace a battery.
   c. Measure battery electrolyte with an hydrometer.
   d. Load test a battery.
   e. Charge test a battery for three minutes.

STORAGE BATTERIES
UNIT II

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined in the job sheets.

G. Demonstrate the use of a battery charger.

H. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete job sheets.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Storage Battery Construction

2. TM 2--Battery Plate Groups

STORAGE BATTERIES
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Battery--Two or more connected cells which convert chemical energy into electrical energy (Transparency 1)

B. Cell--One positive plate group and one negative plate group (Transparency 2)

(NOTE: The positive plate contains lead peroxide and the negative plate contains spongy lead.)

C. Plate group--Similar plates welded to a plate strap (Transparency 2)

(NOTE: Plate groups are interlaced, with positive and negative plates alternating, but separated to allow free flow of electrolyte.)

D. Electrolyte--Solution of water and sulphuric acid

E. Specific gravity--Weight of liquid compared to an equal volume of water at 60°F

(NOTE: Water has a specific gravity of 1.0.)

F. Hydrometer--Glass barrel syringe containing a calibrated float used to measure specific gravity

G. Sulfated--Oxidation of positive plate grid wires and formation of lead sulfate crystals which become dense and hard

(NOTE: A sulfated condition is caused by long storage without recharging. A slow charge may or may not restore the battery.)

H. Dissimilar metals--Metals not alike in substance or essentials

II. Functions of the battery

A. Supplies current for cranking the engine

B. Supplies current when the demand exceeds the output of the charging system

C. Stabilizes the voltage in the system during operation

INFORMATION SHEET

III. Purpose of battery parts

A. Plates--Store active material which brings about the chemical reaction to provide electricity

B. Separators--Insulate the negative plates from the positive plates

C. Terminal posts--Connect to conductors for current flow

(NOTE: The positive post is larger than the negative post.)

D. Battery case--Holds the cells and electrolyte to make up the completed battery

E. Vent caps--Close the opening in each cell cover and provide a vent to allow gases to escape (Transparency 3)

F. Cell connector--Connects cells in series

(NOTE: Six-volt batteries have three cells and twelve-volt batteries have six cells connected in series.)

G. Post plate strap--Connects plate groups to terminal posts

IV. Converting chemical energy into electrical energy during the discharging and charging cycle (Transparency 4)

A. Discharging cycle

1. Electrical energy is produced by chemical reaction between the active materials of the dissimilar plates and the sulfuric acid of the electrolyte

2. Lead sulfate is formed at both plates as the battery is discharged, while the sulfuric acid in the electrolyte is replaced by water

B. Charging cycle

1. After the battery is discharged, it must be recharged by a suitable flow of direct current from an external source

2. The specific gravity of the electrolyte increases, sulfuric acid is formed and water is used up

INFORMATION SHEET

V. Battery rating

A. Capacity rated according to quantity of electricity that can be taken from a fully charged battery over a definite period of time

Example: Battery rated at 100 amp-hour should deliver 5 amps continuously for 20 hours

B. Individual cell amperage depends on total plate area, specific gravity, and temperature of electrolyte

(NOTE: Battery efficiency drops from 100% at 80°F to 40% at 0°F.)

VI. Safety rules

A. Wear safety glasses, rubber gloves, and rubber apron when servicing batteries

B. Electrolyte must not be allowed to come in contact with clothing, skin, eyes, or painted surfaces

C. Flush immediately with water any area of skin which acid has contacted

D. Flames or sparks can cause gases given off by battery to explode

(NOTE: Gases given off are hydrogen and oxygen.)

E. Avoid shorting or grounding battery terminals during service

F. Avoid breathing fumes from a battery that is being charged

G. Leave charger in the off position when connecting and disconnecting batteries

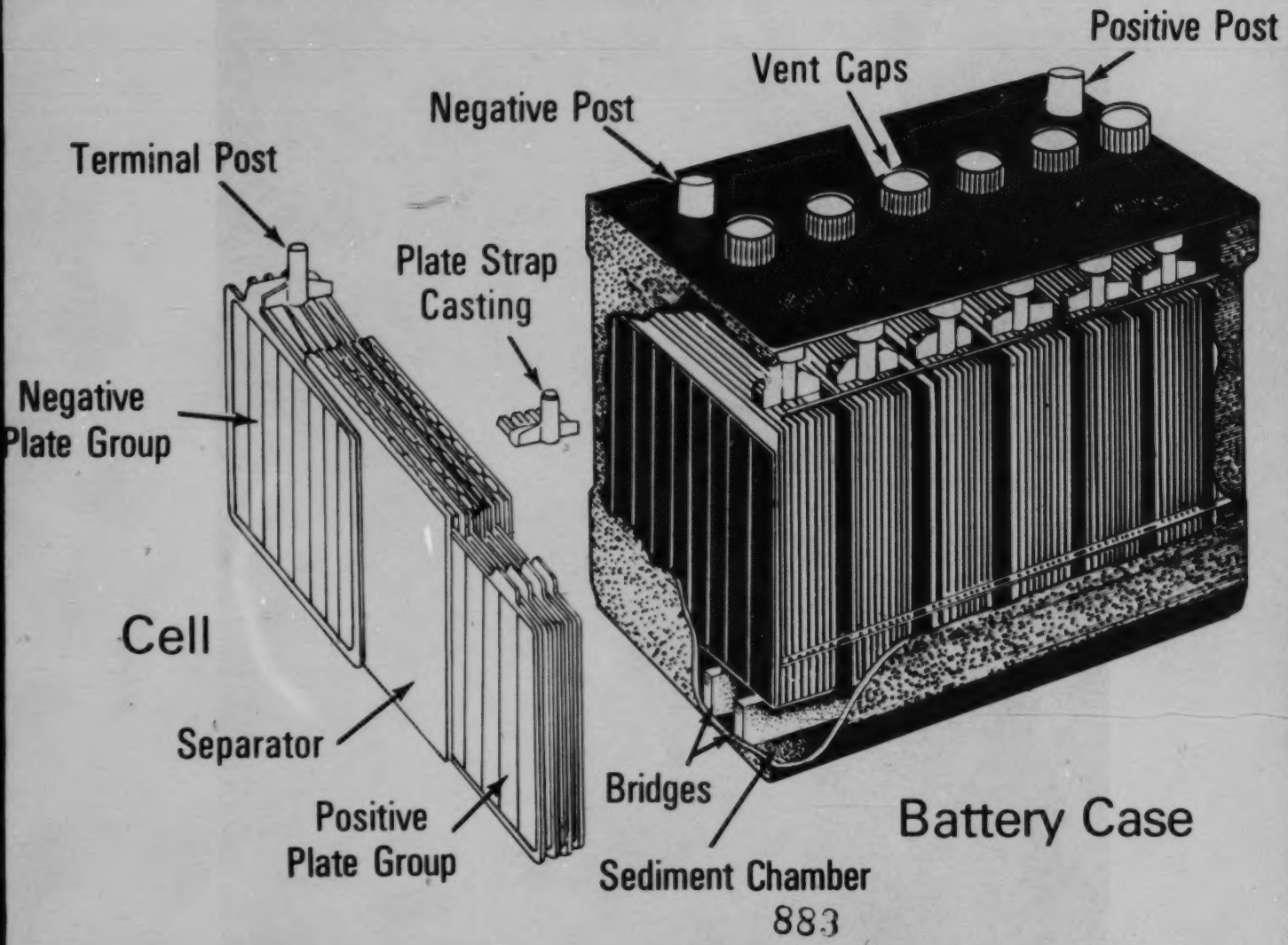
VII. Characteristics of "service free" batteries

A. Case sealed with lifetime supply of electrolyte

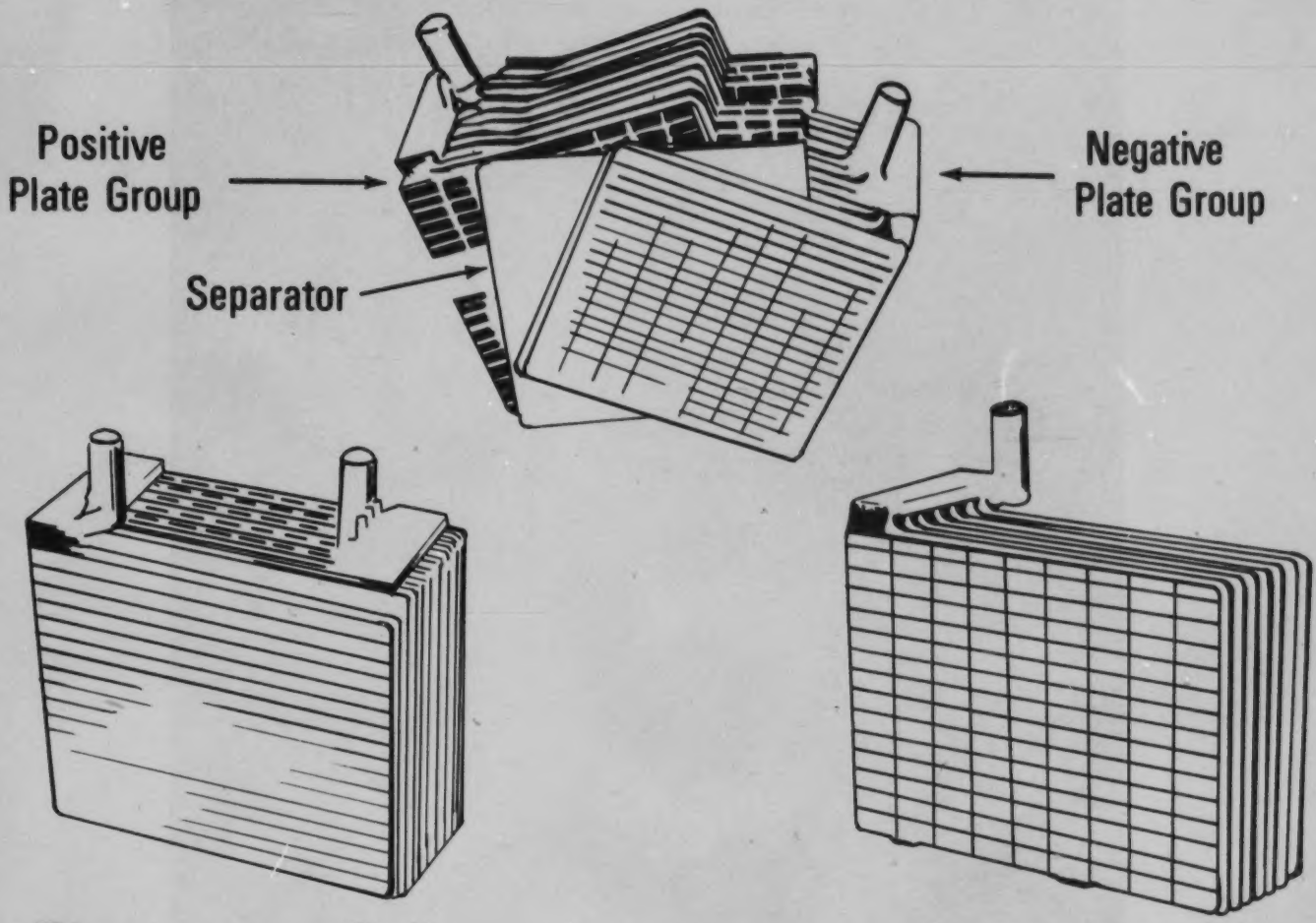
B. Special liquid-gas separator returns any liquid to reservoir

C. Water loss eliminated through the use of special plates

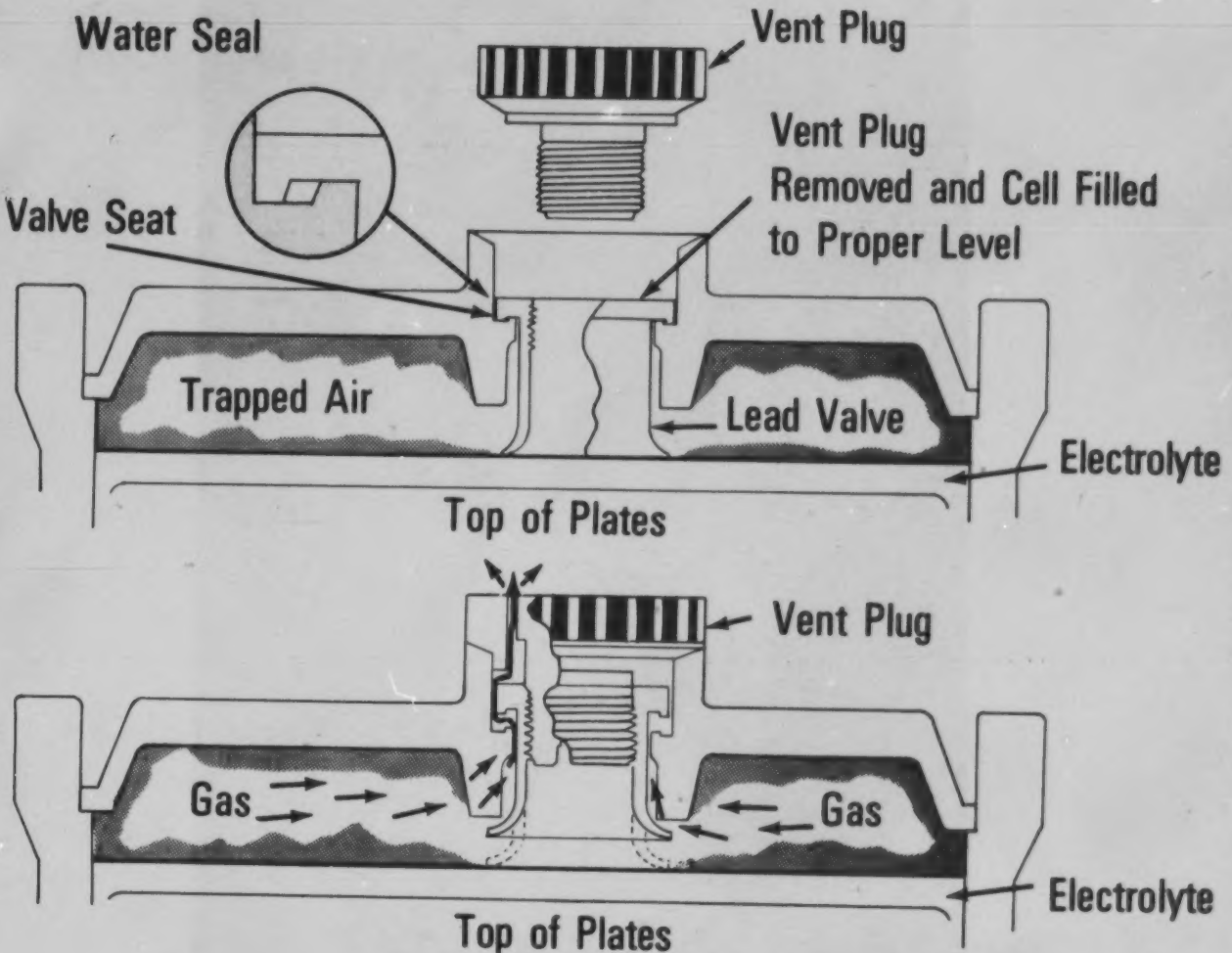
Storage Battery Construction



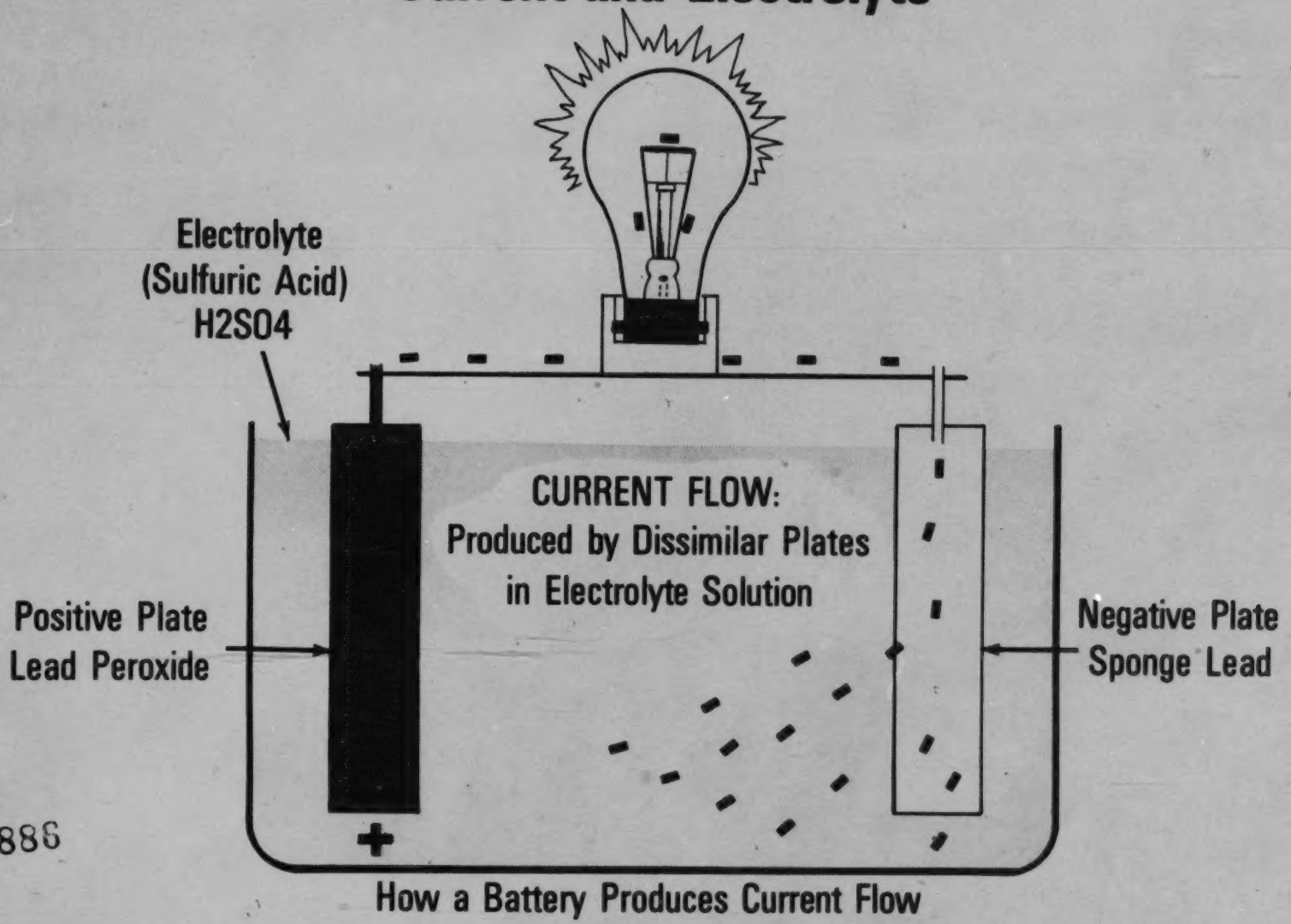
Battery Plate Groups



Vent Caps


Water Seal
Vent Plug
Vent Plug
Removed and Cell Filled
to Proper Level
Valve Seat
Trapped Air
Lead Valve
Electrolyte
Top of Plates
Vent Plug
Gas
Gas
Electrolyte
Top of Plates

Current and Electrolyte



How a Battery Produces Current Flow

886

887

TM 4

D - 67-F

STORAGE BATTERIES
UNIT II

JOB SHEET #1--CLEAN AND SERVICE A BATTERY

I. Tools and materials

A. Safety glasses

B. Rubber gloves

C. Rubber apron

D. Bristle brush

E. Wire brush

F. Screwdriver

G. Battery clamp puller

H. Combination end wrenches

I. Battery pliers

J. Baking soda and water solution (two tablespoons of baking soda to one pint of water)

K. Battery anti-corrosion paste

L. Shop towels

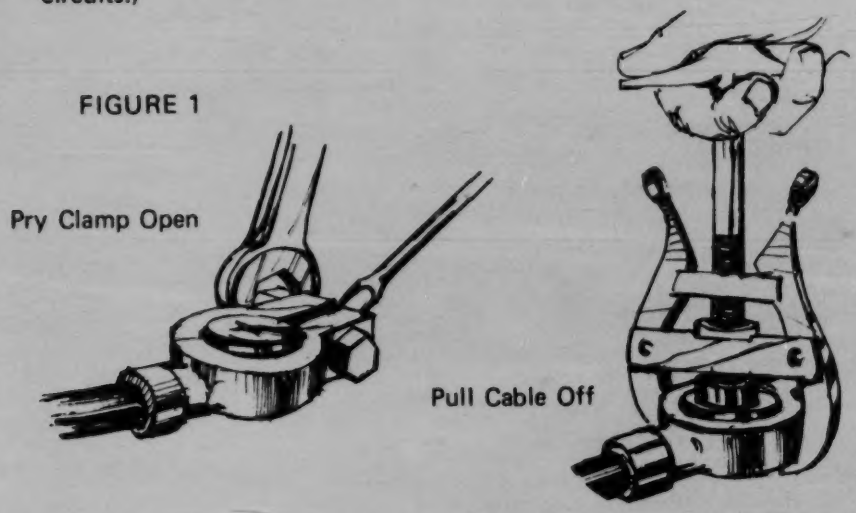
JOB SHEET #1

II. Procedure

A. Disconnect battery cables from the battery posts (Figure 1)

(NOTE: Always disconnect the grounded battery cable first to avoid short circuits.)

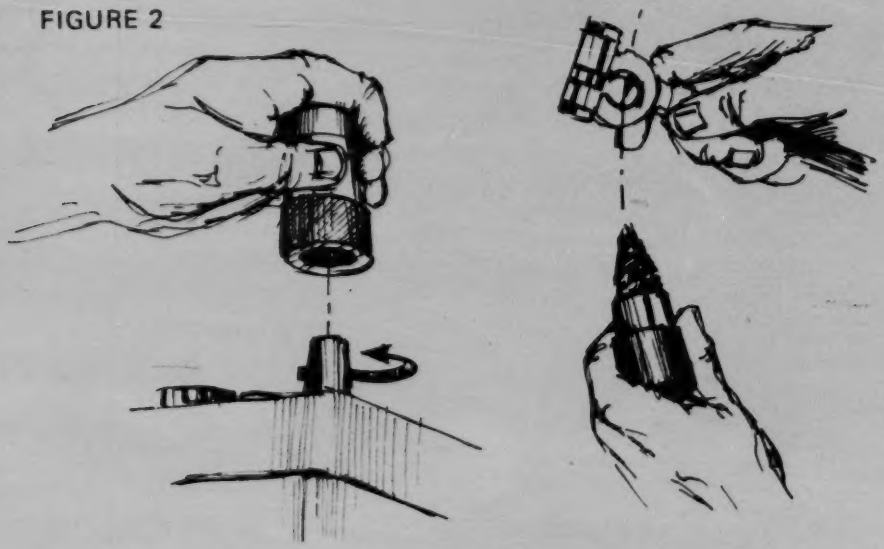
FIGURE 1



B. Clean battery cable clamps and battery post (Figure 2)

(NOTE: Battery posts and inside of battery cable clamps must be clean and bright.)

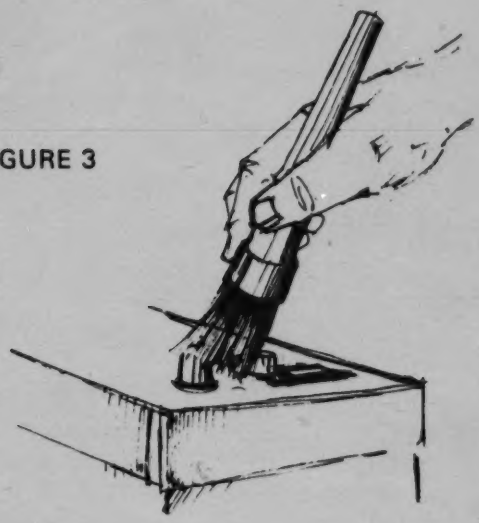
FIGURE 2



JOB SHEET #1

C. Remove loose dirt and corrosion particles from top of battery (Figure 3)

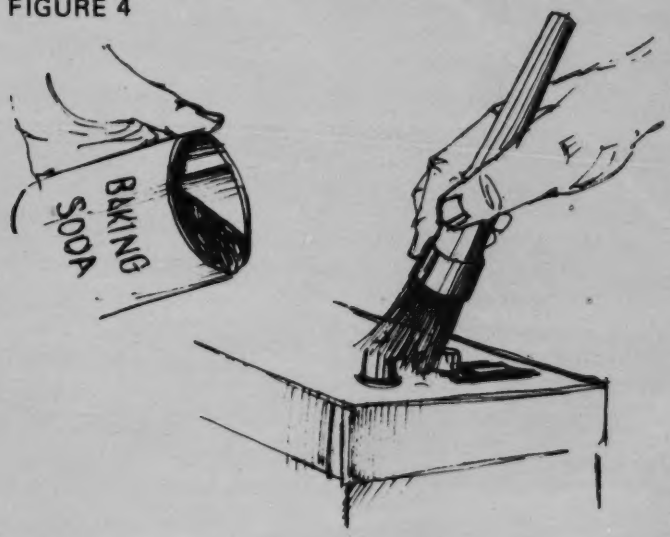
FIGURE 3



D. Brush soda water solution on battery, battery post, clamps, and battery hold-down (Figure 4)

(NOTE: Keep water and soda from entering the battery through the vent holes in the vent caps.)

FIGURE 4



JOB SHEET #1

E. Wash away residue with clean water (Figure 5)

(NOTE: Remove all residue that may have lodged around battery, frame, or parts of the vehicle.)

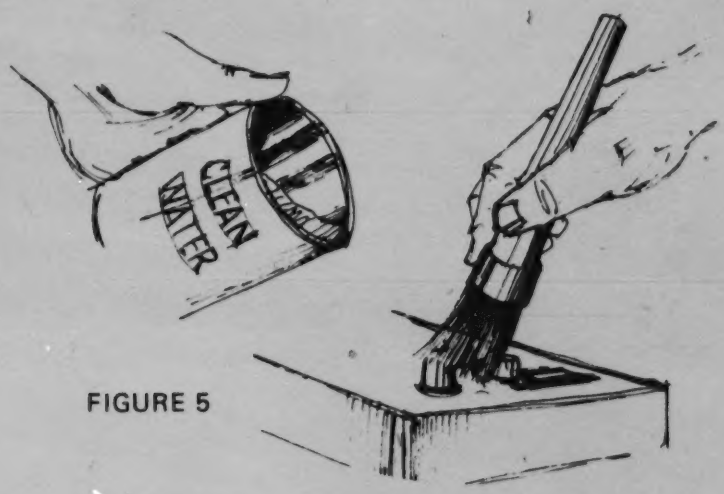


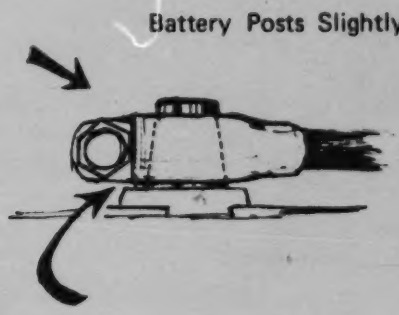
FIGURE 5

F. Dry the battery and battery cables with a clean cloth

G. Reconnect battery cables to the battery posts (Figure 6)

(CAUTION: Always reconnect the power cable first and the ground cable last.)

FIGURE 6



H. Spread a coating of battery anti-corrosion paste over the cable clamps and terminals

I. Remove vent caps and check electrolyte level in all cells

J. Add water if necessary to bring electrolyte up to proper level

(NOTE: Do not overfill.)

STORAGE BATTERIES
UNIT II

JOB SHEET #2--REMOVE AND REPLACE A BATTERY

I. Tools and materials

A. Safety glasses

B. Rubber gloves

C. Rubber apron

D. Wire brush

E. Screwdriver

F. Battery clamp puller

G. Combination end wrenches

H. Battery pliers

I. Battery cable spreader

J. Battery post and cable cleaner

K. Battery lift strap

JOB SHEET #2

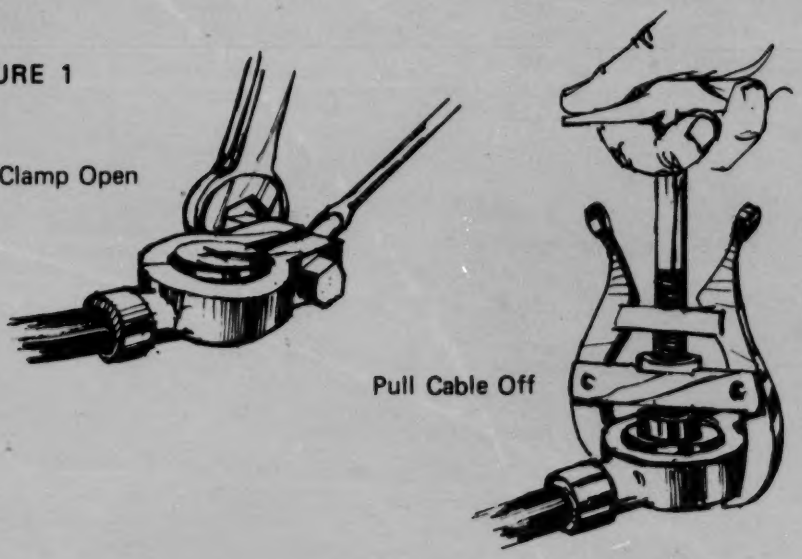
II. Procedure

(NOTE: Observe the location of the positive post so the battery can be installed in the same way.)

A. Disconnect the battery cables from the battery posts (Figure 1)

(NOTE: Always disconnect the grounded battery cable first to avoid short circuits. Use care to avoid twisting the battery cable post.)

FIGURE 1



B. Remove the battery hold-down

C. Remove the battery from the carrier

(NOTE: Use a suitable battery lift strap to lift the battery.)

D. Inspect the battery carrier for dirt or corrosion

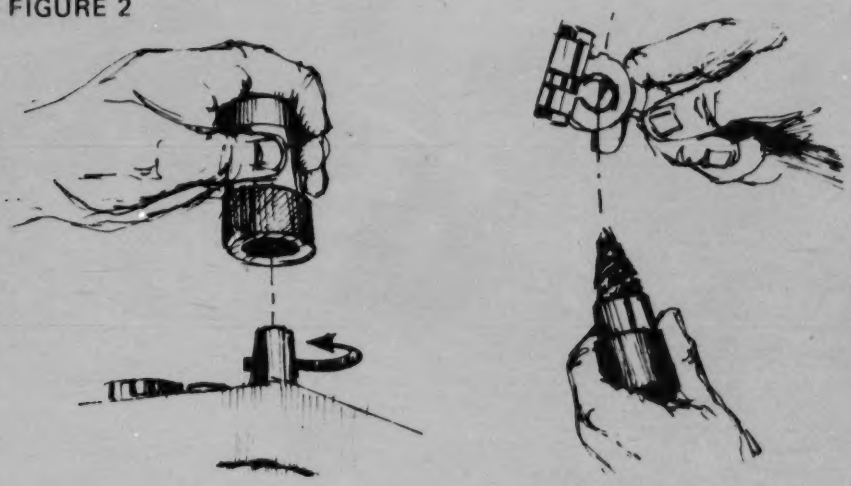
(NOTE: Clean with baking soda and water as required.)

E. Check battery cables for worn or frayed insulation

JOB SHEET #2

F. Clean the inside of battery cables clean and bright (Figure 2)

FIGURE 2



G. Set the battery into place using a lift strap

(NOTE: Position the battery to allow for correct battery cable attachment.)

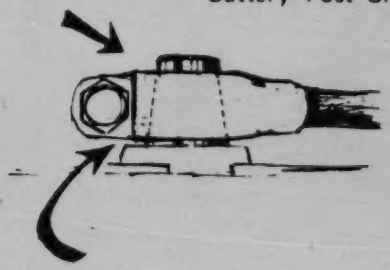
H. Install the battery hold-down clamp or strap and tighten securely

I. Reconnect battery cables to the battery posts (Figure 3)

(NOTE: Always reconnect the power cable first and the ground cable last. Replace clamp bolts and nuts as needed.)

FIGURE 3

Battery Post Slightly Above Clamps



J. Tighten the battery cable clamps securely

(NOTE: Use care to avoid twisting the battery cable post.)

K. Spread a coating of battery anti-corrosion paste over the cable clamps and terminals

STORAGE BATTERIES
UNIT II

JOB SHEET #3--MEASURE BATTERY ELECTROLYTE WITH AN HYDROMETER

I. Tools and materials

A. Hydrometer

B. Shop towels

C. Container clean water

D. Safety glasses

E. Rubber gloves

F. Rubber apron

II. Procedure

A. Remove vent caps from battery

B. Insert the hydrometer into the first cell

C. Squeeze the rubber bulb to draw electrolyte into the hydrometer to suspend the float

(NOTE: If the electrolyte level is too low, add water, charge for one hour, and recheck.)

JOB SHEET #3

D. Take reading at eye level (Figure 1)

(NOTE: Make sure the float is not bumping the top of the hydrometer tube or sticking to the side of the tube. Write down reading for each cell.)

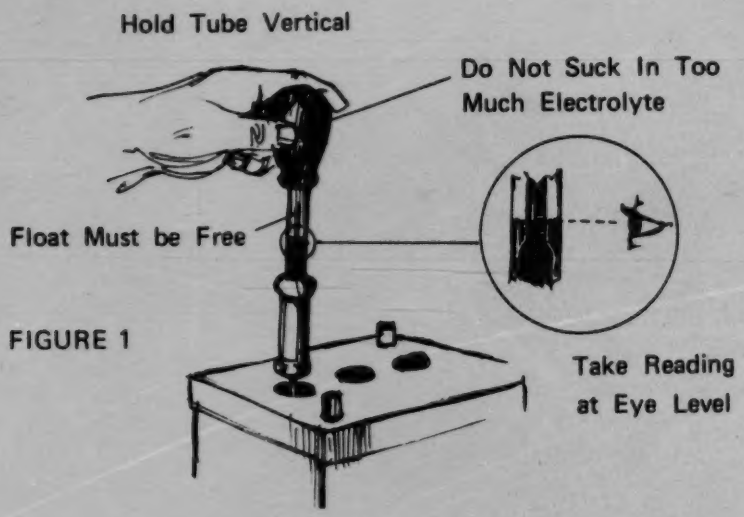


FIGURE 1

E. Squeeze bulb to return electrolyte to cell

F. Repeat for other cells

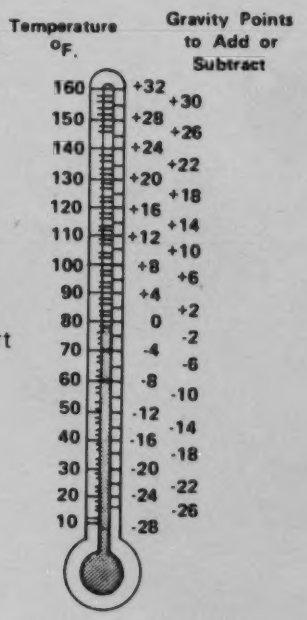
JOB SHEET #3

G. Adjust the readings for temperature

1. Add four gravity points (0.004) to the reading for every 10°F above 80°. Subtract four gravity points (0.004) for each 10° below 80°F (Figure 2)

FIGURE 2

Temperature Adjustment Chart



2. Specific gravity should read from 1.215 to 1.270 (corrected for 80°F electrolyte temperature)

3. The variation in readings between cells should be no more than 0.050

4. If the readings are not within the above mentioned range, charge and retest.

H. Replace vent caps upon completion of test

I. Flush any spilled electrolyte with clean water

STORAGE BATTERIES
UNIT II

JOB SHEET #4--LOAD TEST A BATTERY

I. Tools and materials

A. Battery capacity tester

B. Appropriate conductors

C. Safety glasses

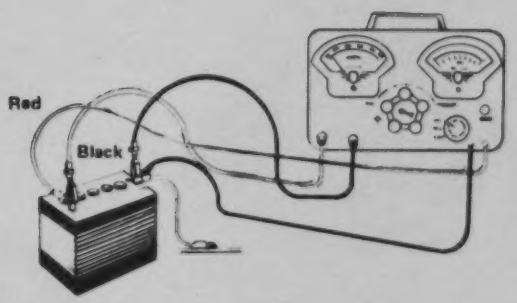
D. Rubber gloves

E. Rubber apron

II. Procedure

A. Connect tester (Figure 1)

FIGURE 1



Battery Capacity Test - 12V Battery

B. Tighten rheostat knob to apply a load to battery

C. Apply load equal to three times the ampere-hour rating of battery being tested

(NOTE: Ampere-hour rating should be marked on the outside of battery case.)

D. Read battery voltage at the end of 15 seconds

(NOTE: If voltage drops below 1.5 volts per cell in 15 seconds use the 3-minute charge test.)

E. Loosen rheostat to relieve load at end of 15 seconds

F. Disconnect tester

STORAGE BATTERIES
UNIT II

JOB SHEET #5--CHARGE TEST A BATTERY FOR THREE MINUTES

I. Tools and materials

A. Adjustable, fast rate battery charger

B. Battery capacity tester

C. Appropriate conductors

D. Safety glasses

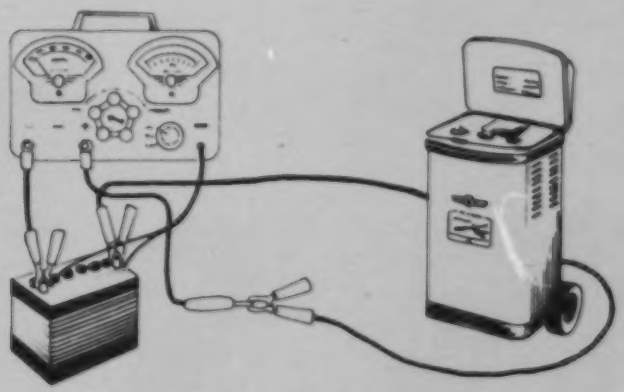
E. Rubber gloves

F. Rubber apron

II. Procedure

A. Connect tester and charger (Figure 1)

FIGURE 1



Battery Charge Test - 12V Battery

B. Turn charger on and adjust the charging rate to 40 amps

C. Charge battery for 3 minutes

D. Read individual cell voltages with battery charger still in operation

(NOTE: If they vary by more than 0.1 volt (1.10v), replace the battery.)

E. Read total battery voltage

(NOTE: If it is over 15.5v (15 1/2 volts), the battery is unsatisfactory and must be given a long slow charge and load tested again. If voltage under load test is less than 9v, replace battery.)

STORAGE BATTERIES
UNIT II

NAME_____

TEST

1. Match the terms on the right to the correct definitions.

_____a. Two or more connected cells which convert chemical energy into electrical energy

_____b. One positive plate group and one negative plate group

_____c. Similar plates welded to a plate strap

_____d. Solution of water and sulfuric acid

_____e. Weight of liquid compared to an equal volume of water at 60°F

_____f. Glass barrel syringe containing a calbrated float used to measure specific gravity

_____g. Metals not alike in substance or essentials

_____h. Oxidation of positive plate grid wires and formation of lead sulfate crystals which become dense and hard

1. Electrolyte
2. Hydrometer
3. Specific gravity
4. Dissimilar metals
5. Battery
6. Plate group
7. Sulfated
8. Cell

2. List three functions of the battery.

a.

b.

c.

3. Match the parts of the battery on the right to their purposes.

_____a. Store active material which brings about the chemical reaction to provide electricity	1. Terminal posts
_____b. Insulate the negative plates from the positive plates	2. Battery case
_____c. Connect to conductors for current flow	3. Plates
_____d. Holds the cells and electrolyte to make up the completed battery	4. Separators
_____e. Close the opening in each cell cover and provide a vent to allow gases to escape	5. Cell connector
_____f. Connects cells in series	6. Vent caps
_____g. Connects plate groups to terminal posts	7. Post plate strap

4. Discuss the process by which a battery converts chemical energy into electrical energy during the discharging and charging cycle.

5. Explain the term battery rating.

6. Select safety rules to be observed during the care and maintenance of batteries by placing an "X" in the appropriate blanks.

_____a. Electrolyte must not be allowed to come in contact with clothing, skin, eyes, or painted surfaces

_____b. Flames or sparks can cause gases given off by battery to explode

_____c. Wear safety glasses, rubber gloves, and rubber apron when servicing batteries

_____d. Leave charger in the on position when connecting and disconnecting batteries

_____e. Flush immediately with water any area of skin which acid has contacted

_____f. Avoid breathing fumes from a battery that is being charged

7. Name three characteristics of "service free" batteries.

a.

b.

c.

8. Demonstrate the ability to:

a. Clean and service a battery.

b. Remove and replace a battery.

c. Measure battery electrolyte with an hydrometer.

d. Load test a battery.

e. Charge test a battery for three minutes.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

STORAGE BATTERIES
UNIT II

ANSWERS TO TEST

1. a. 5
   b. 8
   c. 6
   d. 1
   e. 3
   f. 2
   g. 4
   h. 7

2. a. Supplies current for cranking the engine
   b. Supplies current when the demand exceeds the output of the charging system
   c. Stabilizes the voltage in the system during operation

3. a. 3
   b. 4
   c. 1
   d. 2
   e. 6
   f. 5
   g. 7

4. Discussion should include:
   a. Discharging cycle
      1) Electrical energy is produced by chemical reaction between the active materials of the dissimilar plates and the sulfuric acid of the electrolyte
      2) Lead sulfate is formed at both plates as the battery is discharged, while the sulfuric acid in the electrolyte is replaced by water
   b. Charging cycle
      1) After the battery is discharged, it must be recharged by a suitable flow of direct current from an external source
      2) The specific gravity of the electrolyte increases, sulfuric acid is formed and water is used up

5. Explanation should include:

   a. Capacity rated according to the quantity of electricity that can be taken from a fully charged battery over a definite period of time

   b. Individual cell amperage depends on total plate area, specific gravity, and temperature of electrolyte

6. a, b, c, e, f

7. a. Case sealed with lifetime supply of electrolyte

   b. Special liquid-gas separator returns any liquid to reservoir

   c. Water loss eliminated through the use of special plates

8. Performance skills evaluated to the satisfaction of the instructor

STARTING CIRCUITS
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to name the major parts in a starting circuit and match the parts to their functions. The student should also be able to disassemble, test, and reassemble starting motors. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with starting circuits to the correct definitions.
2. Explain the purpose of the starting circuit.
3. Name four major parts in the starting circuit.
4. Match the major parts in the starting circuit to their functions.
5. Name four major parts of a starting motor.
6. Match the component parts of the starting motor to their functions.
7. Explain how a basic starting motor converts electrical energy into mechanical energy.
8. Explain how a starting motor is kept running.
9. Discuss the current flow in a starting motor circuit.
10. Identify four types of starter field circuits.
11. Match the types of starter field circuits to the current flow in each type circuit.
12. Discuss counter electromotive force in relation to armature speed.
13. Name four types of switches for starting motors.
14. Distinguish between a magnetic switch and a solenoid switch.
15. Discuss the operation of the series-parallel switch.
16. Explain two ways starter drives are engaged.

17. List three types of electromagnetic or lever shift drives.

18. Demonstrate the ability to:

    a. Remove and replace a starter.

    b. Disassemble, test, and reassemble a starter.

    c. Test starter circuit (no load).

    d. Recondition starting motor armature.

STARTING CIRCUITS
UNIT III

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheets.

F. Demonstrate and discuss the procedures outlined in the job sheets.

G. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete job sheets.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Starter Motor Component Parts
2. TM 2--Components of Armature
3. TM 3--Parts in Starting Circuit
4. TM 4--Starting Motor

5. TM 5--Starter Field Circuits

6. TM 6--Types of Motor Switches

7. TM 7--Series-Parallel Switch and Starter Circuit

8. TM 8--Types of Electromagnetic or Lever Shift Drives

D. Job sheets

1. Job Sheet #1--Remove and Replace a Starter

2. Job Sheet #2--Disassemble, Test, and Reassemble a Starter

3. Job Sheet #3--Test Starter Circuit (No Load)

4. Job Sheet #4--Recondition Starting Motor Armature

E. Test

F. Answers to test

II. References:

A. *Fundamentals of Service: Electrical Systems.* Moline, Illinois: Deere and Company, 1968.

B. Billiet, Walter E. and Goings, Leslie F. *Automotive Electrical Systems*, Third Edition. Chicago, Illinois: American Technical Society, 1970.

C. Crouse, William H. *Automotive Mechanics.* New York, New York: Webster Division/McGraw-Hill Book Company, 1965.

STARTING CIRCUITS
UNIT III

INFORMATION SHEET

I. Terms and definitions (Transparencies 1 and 2)

A. Pole pieces--Ends of a magnet in the field frame assembly of a starting motor

B. Field winding--Wire wrapped around pole pieces to increase the strength of the magnetic field when current is passed through the windings

C. Armature--Main drive of starter motor; converts electrical energy into mechanical energy

D. Commutator--Metal segments attached to ends of wire loops to form contact surface on armature

E. Brushes--Sliding contacts to feed electrical energy from battery to commutator

F. Pinion--Small gear that meshes with a larger gear

G. Solenoid--Electromagnetic switch that closes circuit and engages the motor drive pinion with the flywheel

H. Motor switch--Manual, magnetic, or solenoid switch

I. Inertia--Tendency of a body in motion to remain in motion

J. CEMF--Counter electromotive force

II. Purpose of starting circuit--Converts electrical energy from the battery into mechanical energy at the starting motor to crank the engine (Transparency 3)

III. Major parts in starting circuit (Transparency 3)

A. Battery

B. Starter switch

C. Motor switch

D. Starting motor

INFORMATION SHEET

IV. Function of parts of starting circuit

A. Battery--Supplies energy for the circuit

B. Starter switch--Activates the circuit

C. Motor switch--Closes circuit to motor and engages motor drive with flywheel

D. Starting motor--Drives flywheel to start engine

V. Major parts of starting motor (Transparencies 1 and 4)

A. Motor switch

B. Field frame assembly

C. Armature

D. Drive mechanism

VI. Component parts and functions (Transparency 4)

A. Pole shoe--Forms a magnetic field of force around armature

B. Field winding--Wrapped around pole shoe to strengthen magnetic field when current is passed through the winding

C. Armature--Converts electrical energy into mechanical energy to drive mechanism to crank engine

(NOTE: The magnetic field around the loop and the field between the pole shoes repel each other causing the loop or armature to turn.)

D. Commutator--Forms contact surface for battery to feed electrical current through armature

E. Brushes--Sliding contacts which feed electrical energy to the commutator

VII. Conversion of electrical energy into mechanical energy--Current carrying conductor (armature) formed in a loop and mounted on a shaft, will cause the shaft to rotate when placed inside a magnetic field (field windings)

VIII. How a starting motor is kept running (Transparency 2)

A. The magnetic field around the armature and the magnetic field between the pole pieces repel each other causing the armature to turn

INFORMATION SHEET

B. Metal segments on the ends of the commutator make a one-half turn reversing their connection through sliding contacts (brushes) which causes the current to flow in the opposite direction in the armature windings

IX. Current flow in a starting motor circuit--Current will flow from battery, through cable, across switch contacts, through field windings and armature, and back to battery through ground (Transparency 3)

X. Types of starter field circuits (Transparency 5)

A. Series-wound

B. Parallel-wound

C. Series-parallel-wound

D. Compound-wound

XI. Types of starter field circuits and current flow (Transparency 5)

A. Series-wound--Current flows through all the field windings before it flows through the two insulated brushes to the armature

B. Parallel-wound--Current flows through one field winding to the brushes, and also through the other field winding to the brushes, placing the field windings in parallel

C. Series-parallel-wound--One third of the current flows through each pair of field windings to one of the three insulated brushes

D. Compound-wound--One or more of the poles is shunt wound, connected directly to ground to prevent excessive speeds

(NOTE: The shunt coil is not affected by the counter voltage (CEMF) induced into the armature windings when passing through the magnetic field of the field coils.)

XII. Counter electromotive force in relation to armature speed

A. Counter voltage (CEMF) is induced into the armature windings when they pass through the magnetic field of the field coils

B. The faster the armature turns the higher the counter voltage

C. The compound-wound starter shunt winding prevents excessive speeding because the shunt winding is connected directly to ground, reducing the series field winding, armature current flow, and armature free speed

INFORMATION SHEET

XIII. Types of switches for starting motors (Transparencies 6 and 7)

- A. Manual
- B. Solenoid
- C. Magnetic
- D. Series-parallel

XIV. Magnetic and solenoid switches (Transparency 6)

- A. Magnetic--Normally used with bendix drive as switch does not provide mechanical shifting of drive mechanism
- B. Solenoid--Provides a mechanical means of shifting pinion into mesh with flywheel

XV. Operation of series-parallel switch (Transparency 7)

- A. Starter switch closes, connecting two 12 volt batteries in series with the starting motor
- B. Solenoid circuit is completed by a set of points mechanically closed by the series-parallel switch plunger and starter turns over
- C. Starter switch is released, going into neutral position, permitting operation of electrical equipment by two 12 volt batteries in parallel for normal operation

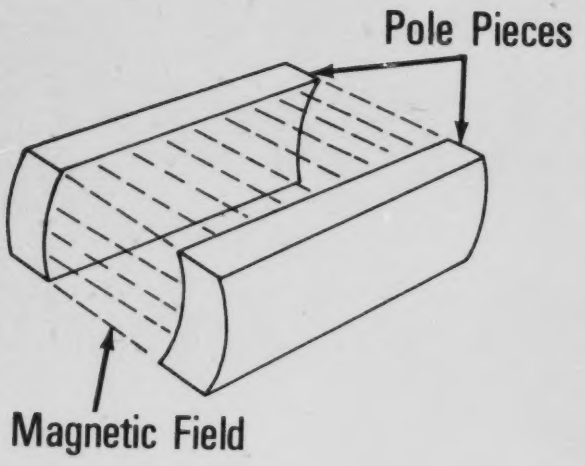
XVI. Engaging starter drives

- A. Inertia of armature acting through drive mechanism
- B. Electromagnetic plunger to mechanically shift pinion into mesh

XVII. Types of electromagnetic or lever shift drives (Transparency 8)

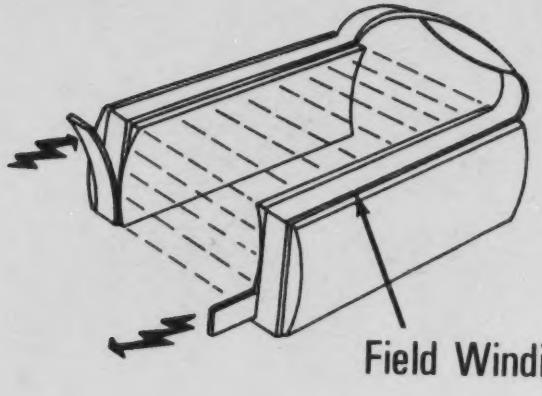
- A. Overrunning clutch
- B. Dyer drive
- C. Sprag clutch drive

Starter Motor Component Parts



POLE PIECES AND THEIR MAGNETIC FIELD

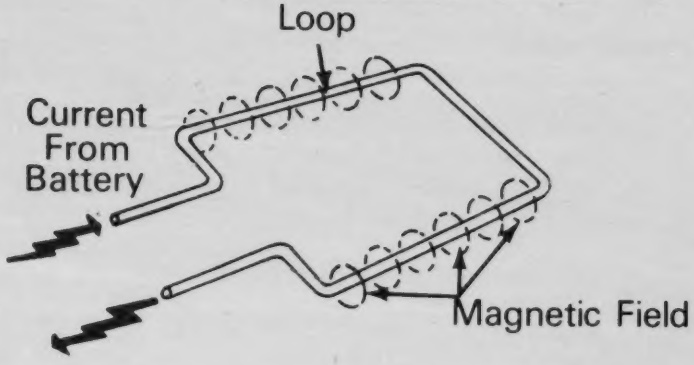
913



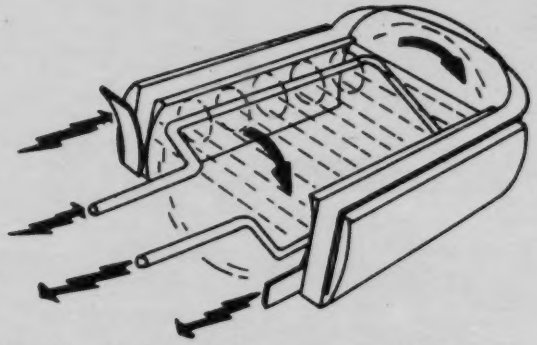
FIELD WINDING ADDED TO POLE PIECES

914

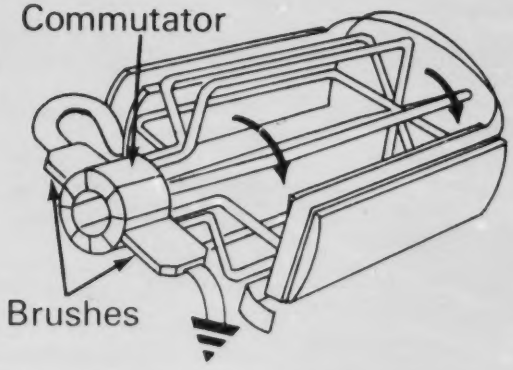
Components of Armature



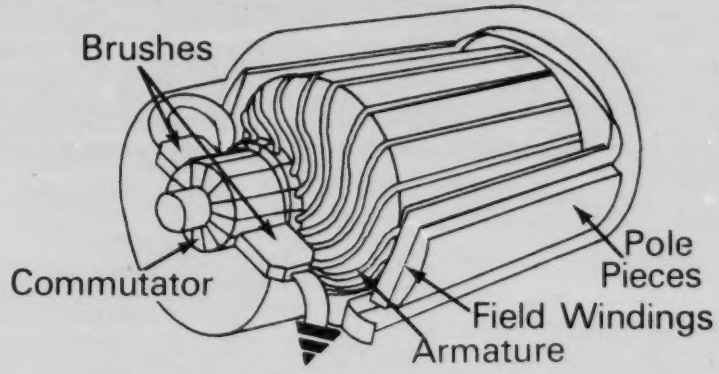
LOOP OF "LIVE" WIRE AND ITS MAGNETIC FIELD



LOOP PLACED IN FIELD WINDINGS

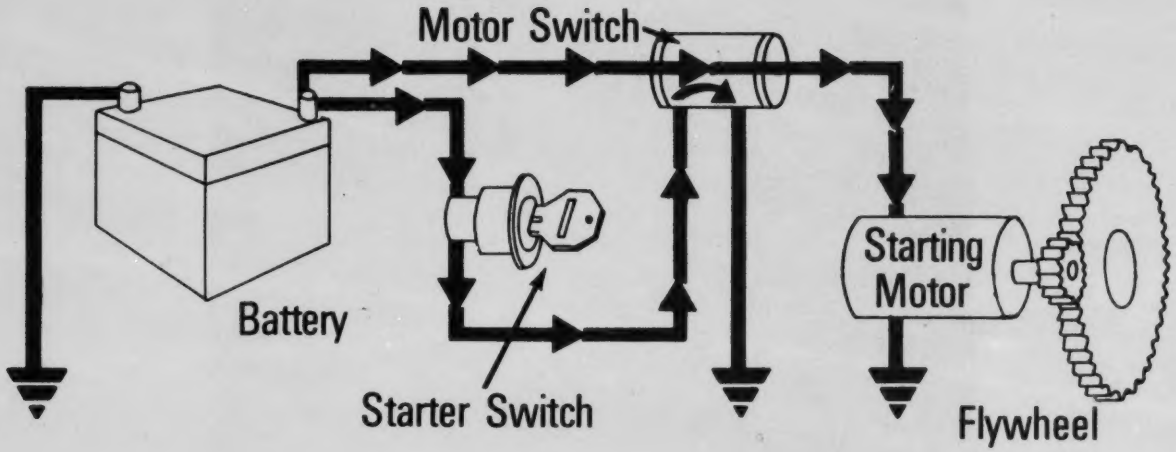


ARMATURE FOR STARTING MOTOR

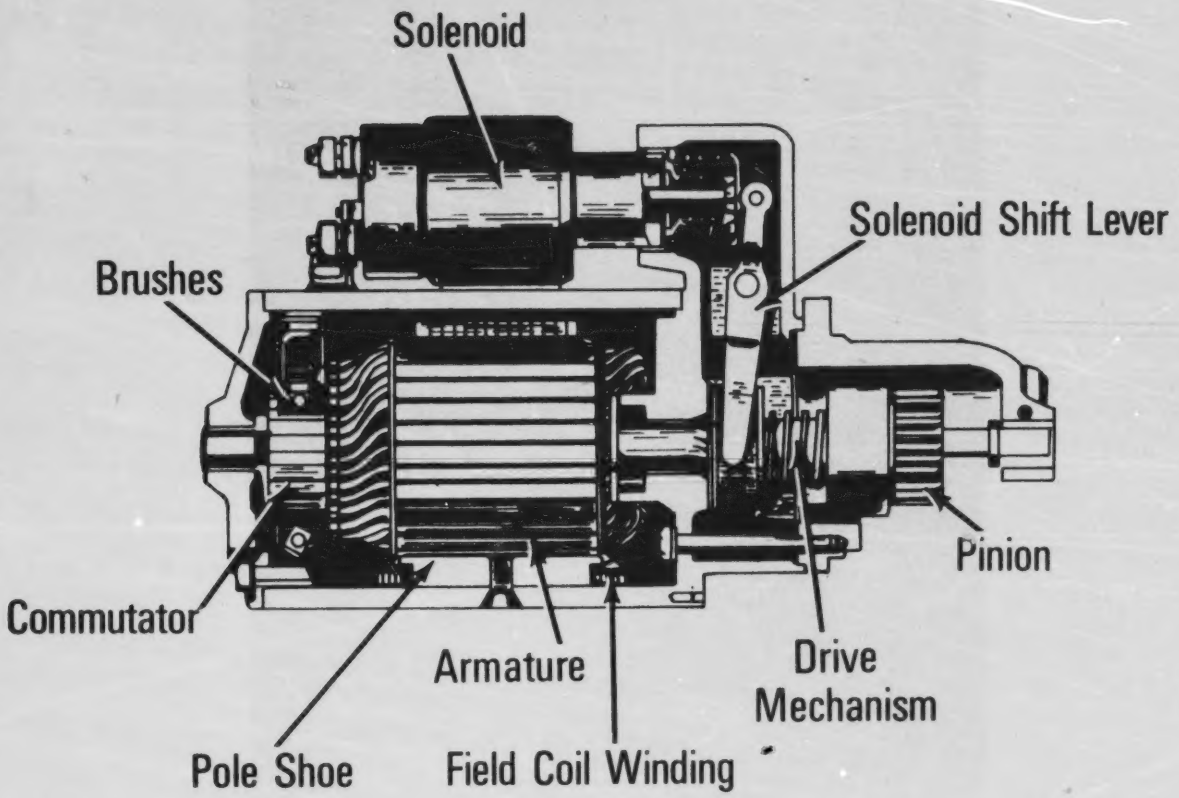


ARMATURE AND BRUSHES

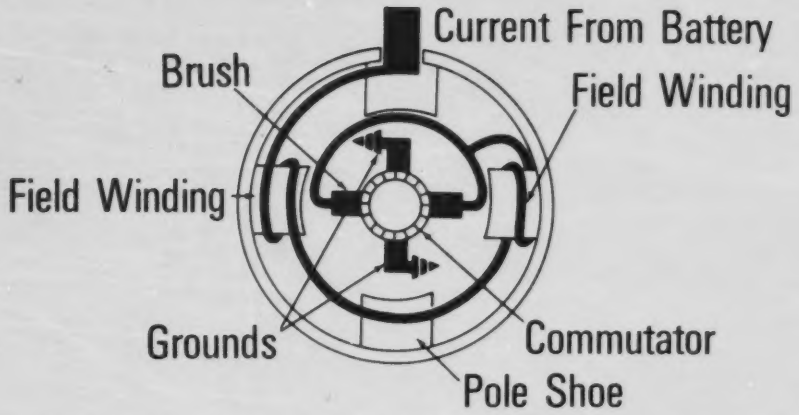
Parts in Starting Circuit



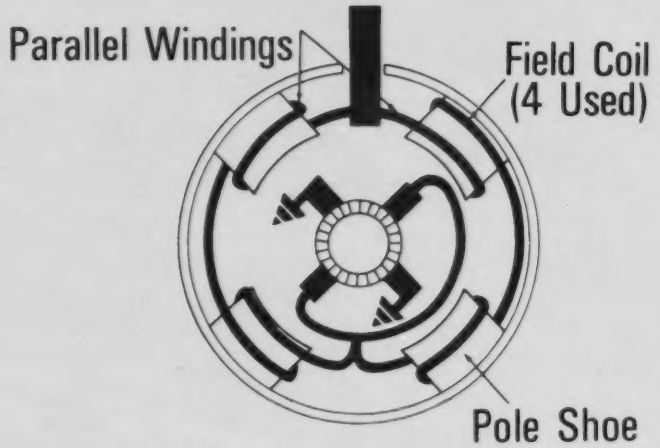
Starting Motor



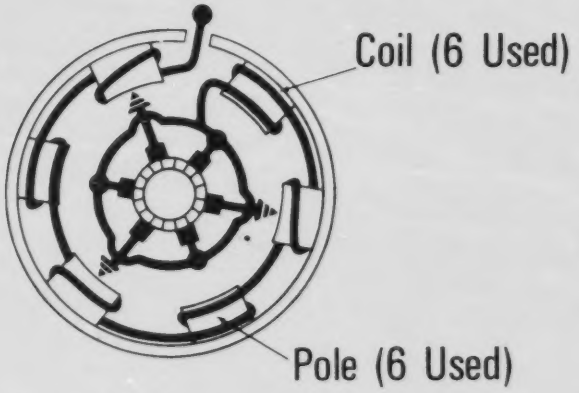
Starter Field Circuits



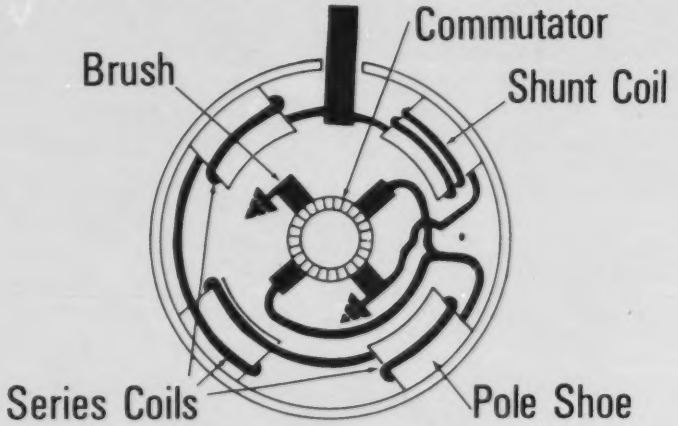
FOUR-POLE –TWO-COIL SERIES-WOUND MOTOR



FOUR-POLE–FOUR-COIL PARALLEL-WOUND MOTOR

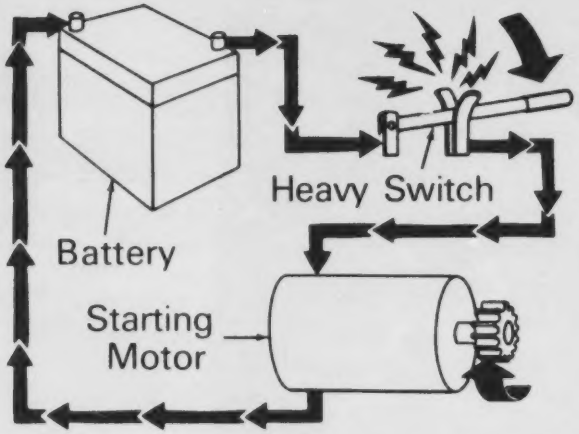


SIX-POLE–SIX-COIL SERIES-PARALLEL-WOUND MOTOR

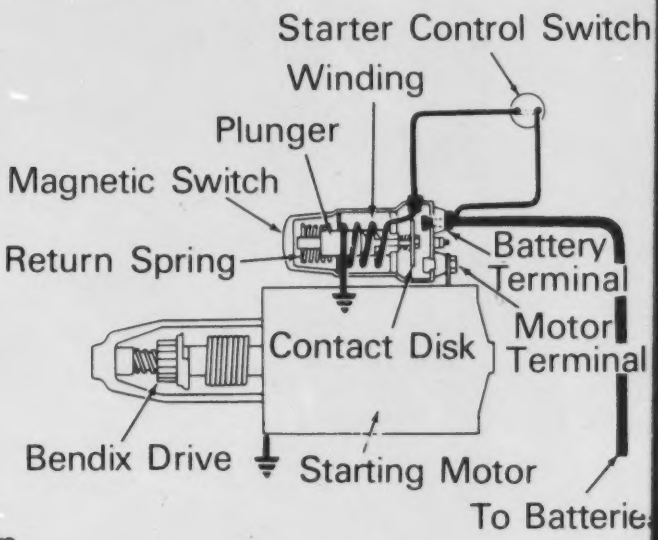


COMPOUND-WOUND MOTOR

Types of Motor Switches

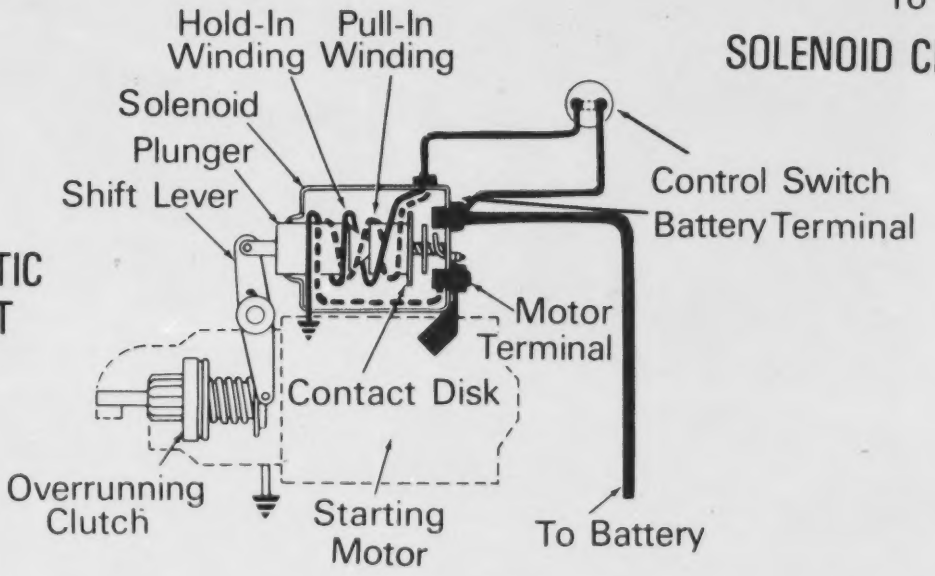


MANUAL SWITCH

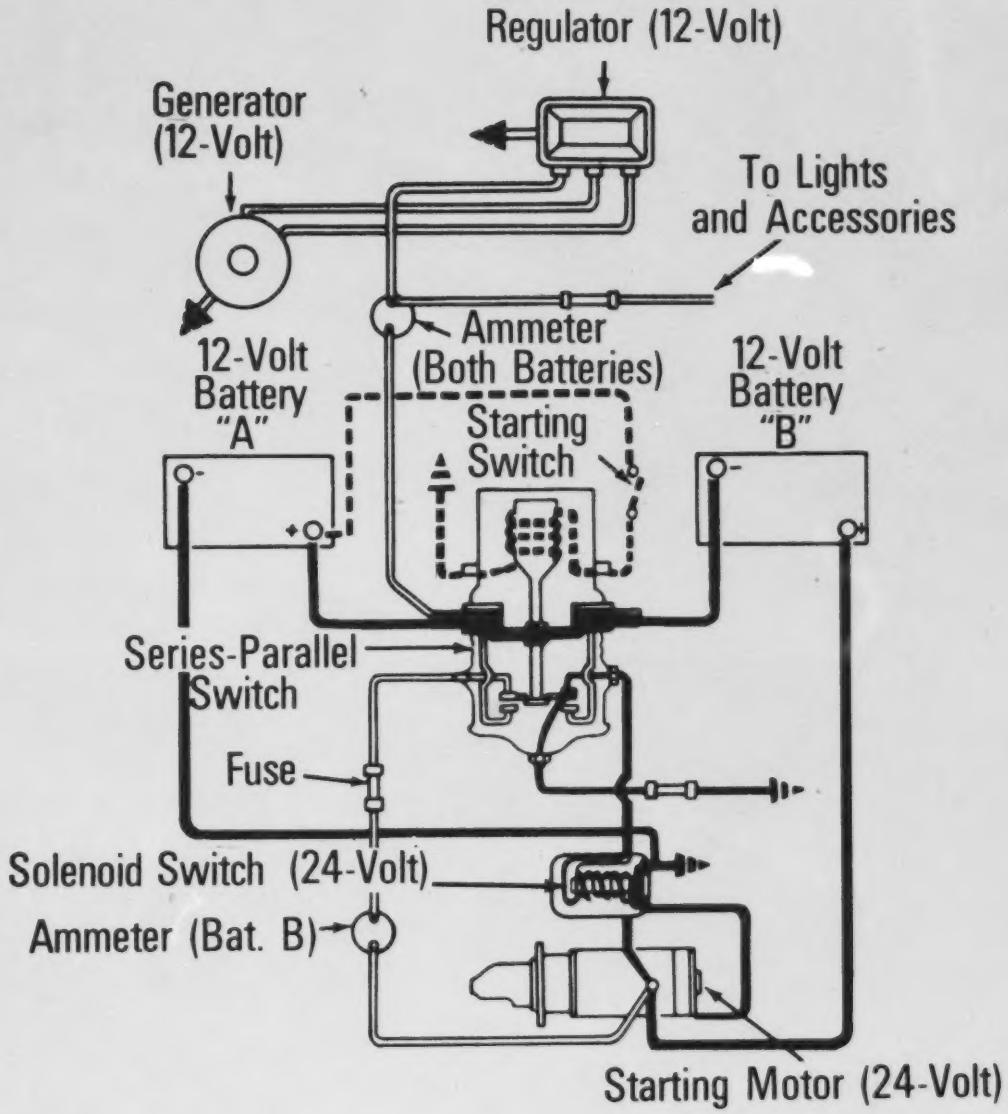


SOLENOID CIRCUIT

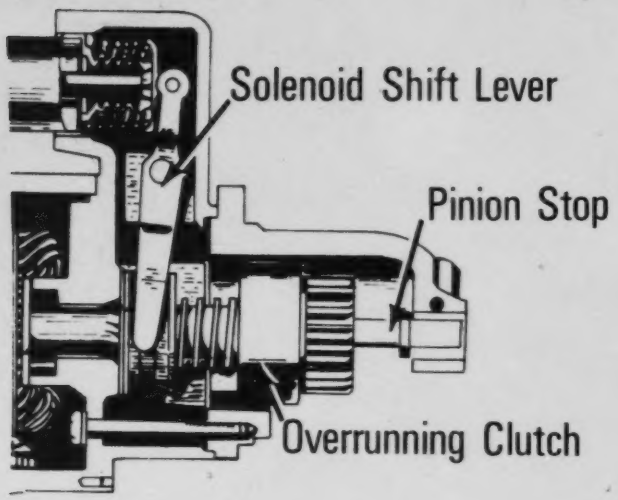
TYPICAL MAGNETIC SWITCH CIRCUIT

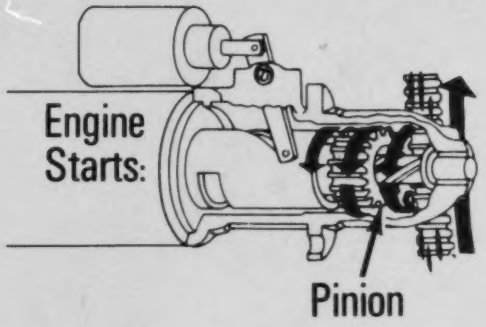


Series-Parallel Switch and Starter Circuit

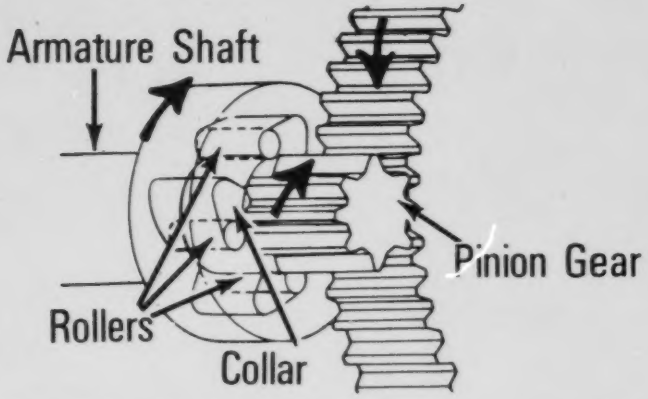


Types of Electromagnetic or Lever Shift Drives

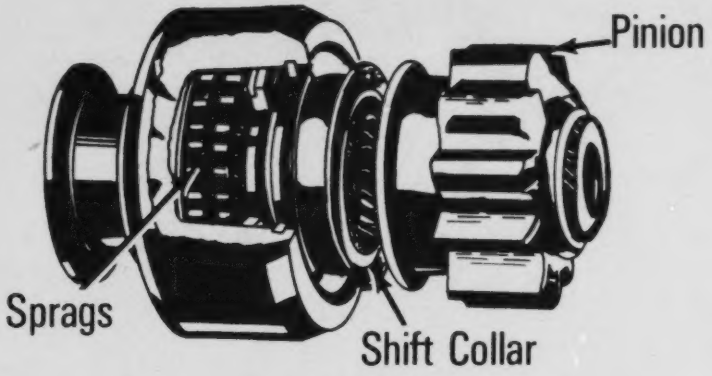




DYER DRIVE IN OPERATION: 3) FLYWHEEL SPINNING PINION OUT OF MESH



OVERRUNNING CLUTCH DRIVE ENGAGED



SPRAG CLUTCH DRIVE

STARTING CIRCUITS
UNIT III

JOB SHEET #1--REMOVE AND REPLACE A STARTER

I. Tools and materials

A. Combination end wrenches, 3/8" - 3/4"

B. Sockets, 3/8" - 3/4" by 3/8" drive

C. Ratchet, 3/8" drive

D. Extensions, 3" and 6" by 3/8" drive

E. Small ignition wrench set

F. Battery cable pliers

G. Safety glasses

II. Procedure

A. Remove starter

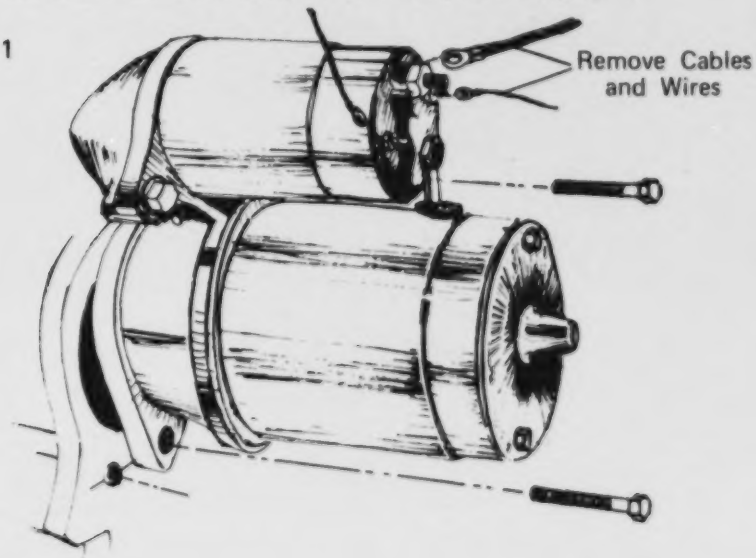
1. Disconnect battery ground cable

2. Remove the cables and electrical wires from the starter

(NOTE: In some cases it may be necessary to remove the starter retaining bolts and allow the starter to be lowered to provide easy removal of the starter wires and cables.)

3. Remove starter retaining bolts as required (Figure 1)

FIGURE 1



JOB SHEET #1

4. Remove other starter brackets if used

5. Remove starter from engine

(CAUTION: Starter motors are heavy and should be handled carefully during removal to avoid damage to the starter or injury to the worker.)

B. Starter replacement

1. Clean starter and block mounting surfaces

2. Position starter in mounting position and start retaining bolts

3. Tighten starter retaining bolts securely

4. Position starter wires and cables in place and start retaining nuts

5. Tighten starter wires and retaining nuts securely

(NOTE: Avoid overtightening and twisting off small retaining nuts.)

6. Replace any brackets that may have been removed and tighten securely

7. Check all connections

8. Replace battery ground cable

9. Start engine two or three times to check starter action

STARTING CIRCUITS
UNIT III

JOB SHEET #2--DISASSEMBLE, TEST, AND REASSEMBLE A STARTER

I. Tools and materials

A. Combination end wrenches, 3/8" - 3/4"

B. Needle nose pliers

C. Pliers (two pair)

D. Hammer

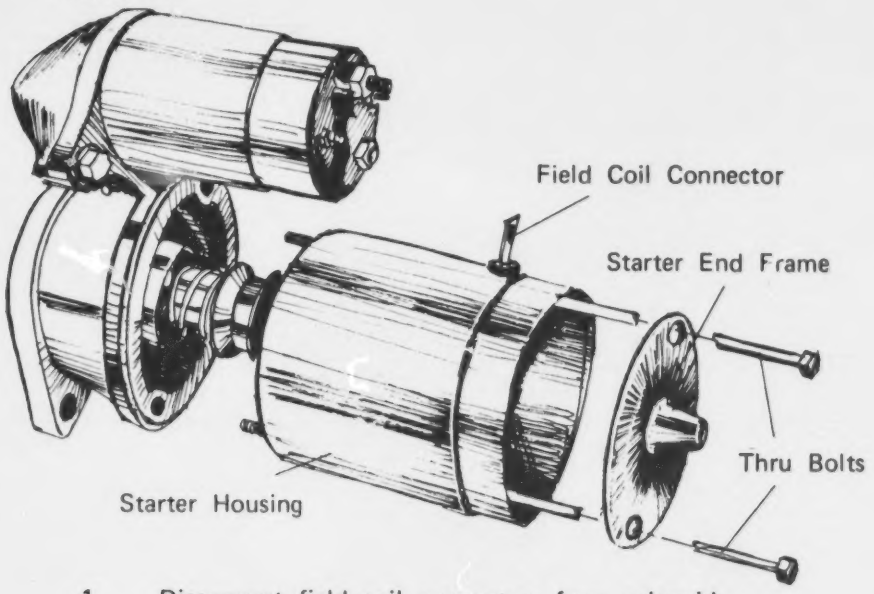
E. Small wood block

F. Suitable armature growler and test light

II. Procedure

A. Disassemble starter (Figure 1)

FIGURE 1



1. Disconnect field coil connectors from solenoid
2. Remove thru bolts
3. Remove starter end frame
4. Grasp starter housing and remove the armature and drive assembly from the housing

JOB SHEET #2

5. Remove the armature and drive assembly from the drive housing

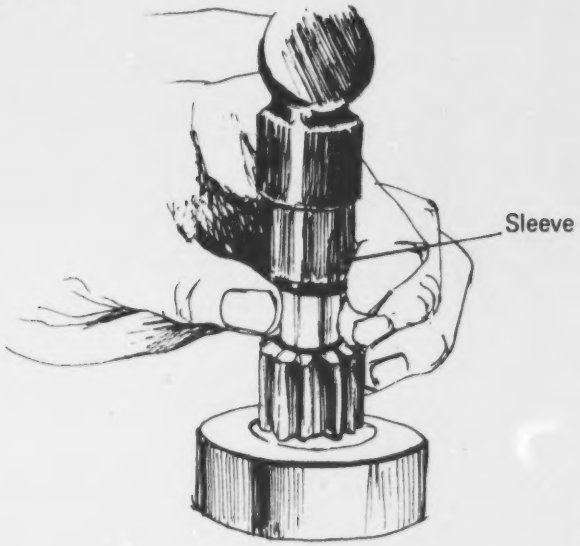
(NOTE: Sometimes the solenoid and shift lever assembly must be removed before the drive assembly and armature can be removed.)

6. Remove starter drive from armature shaft as follows

a. Remove thrust washer

b. Tap retainer toward armature to free the snap ring (Figure 2)

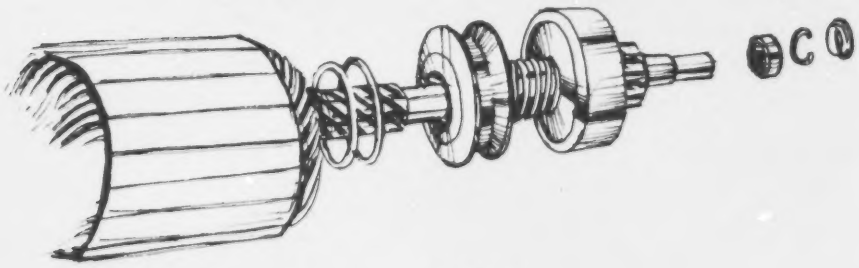
FIGURE 2



c. Remove snap ring and retainer

d. Remove starter drive and assist spring (Figure 3)

FIGURE 3



JOB SHEET #2

7. Remove starter brushes, if required

B. Test and service

1. Clean all starter components

(NOTE: Clean all parts by wiping with clean cloths. The armature, field coils, and starter drive assembly must not be washed in solvent.)

2. Arrange all starter components for inspection

3. Inspect starter bushings for looseness and replace as required

4. Inspect starter brushes for wear

(NOTE: Brushes worn to half their original length or less should be replaced.)

5. Inspect the starter drive

(NOTE: The starter drive pinion gear should turn freely in one direction and lock when turned slowly in the other direction.)

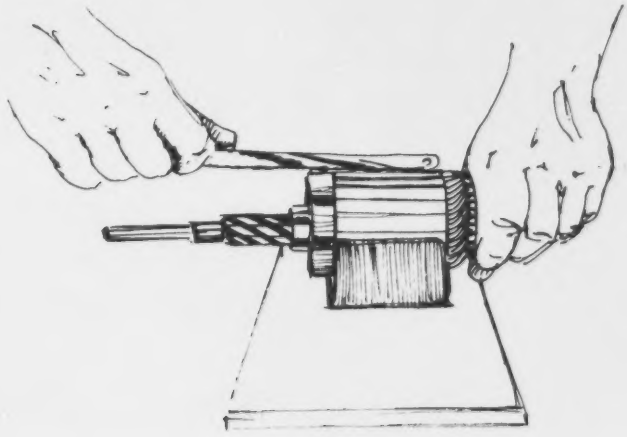
6. Inspect armature commutator

(NOTE: If the armature commutator is rough or out-of-round, it should be turned down using suitable equipment.)

7. Test the armature for short circuits (Figure 4)

(NOTE: Place the armature on a growler and rotate the armature while holding a hacksaw blade over the armature core. If the blade vibrates, the armature is shorted and will require replacement.)

FIGURE 4

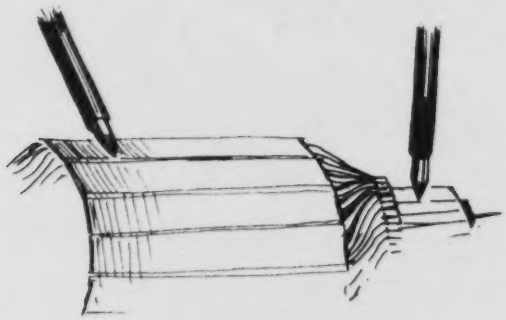


JOB SHEET #2

8. Check armature for ground (Figure 5)

(NOTE: Place one lead of a test lamp on the armature core or shaft and the other on the commutator. If the lamp lights, the armature is grounded and will require replacement.)

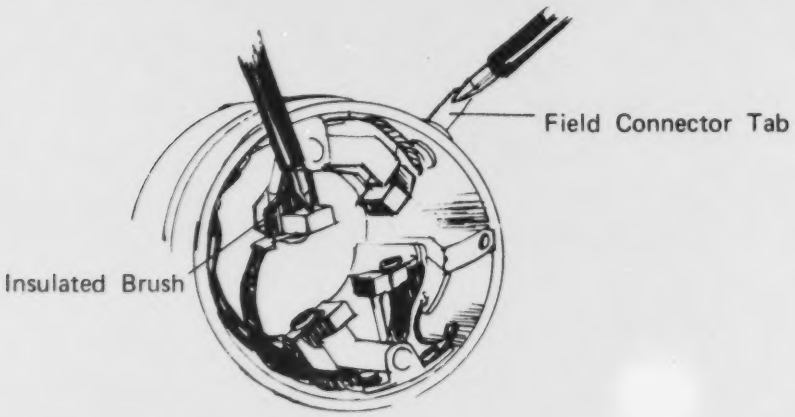
FIGURE 5



9. Check field coil for open circuit (Figure 6)

(NOTE: Place one lead of the test lamp on the insulated brush and the other on the field connection tab. If the lamp does not light, the field coils are open and will require replacement.)

FIGURE 6

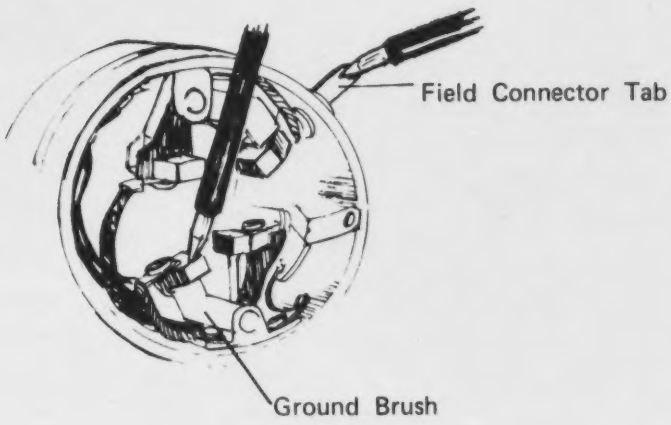


JOB SHEET #2

10. Check field coil for ground (Figure 7)

(NOTE: Place one lead of the test lamp on the field connector tab and the other on the grounded brush. If the lamp lights, the field coils are grounded and will require replacement.)

FIGURE 7

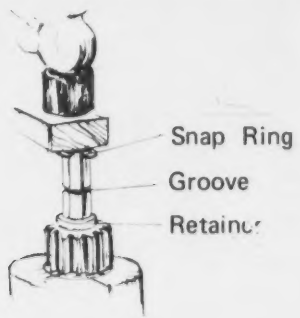


11. After all parts have been tested and inspected, and worn or damaged parts replaced, the starter is ready to be reassembled

C. Reassembly

1. Assemble and install starter brush rigging, if required
2. Attach wires to starter brush assemblies
3. Install starter drive on armature shaft
4. Drive snap ring on shaft (Figure 8)

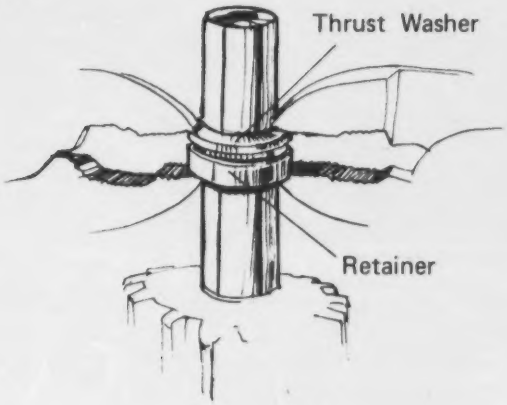
FIGURE 8



JOB SHEET #2

5. Force snap ring into retainer (Figure 9)

FIGURE 9



6. Lubricate drive housing bushing with 4 to 5 drops of light oil
7. Make sure thrust collar is in place against snap ring and retainer
8. Slide armature and starter drive assembly into place in drive housing, engaging shift lever with starter drive as required

   (NOTE: Install solenoid if removed.)
9. Position field frame over armature

   (NOTE: Use care when positioning field frame against drive housing to prevent damage to the brushes.)
10. Place 4 to 5 drops of light oil on starter end frame bushing
11. Place leather brake washer on armature shaft
12. Install starter end frame and start thru bolts
13. Tighten thru bolts evenly and securely
14. Reconnect the field coil connectors to the solenoid
15. Test starter with a battery and jumper cables to determine starter motor performance

STARTING CIRCUITS
UNIT III

JOB SHEET #3--TEST STARTER CIRCUIT (NO-LOAD)

I. Tools and materials

A. Basic hand tool set

B. Starting motor

C. Fully charged battery

D. Ammeter

E. Starter technical manual specifications

F. Voltmeter

G. Carbonpile resistor

H. Tachometer

I. Safety glasses

II. Procedure

A. Inspect starter motor before removal

1. Engage starting motor drive gear and listen for clashing teeth

2. Release motor drive from flywheel and listen for squealing or rattling noise

(NOTE: 1 and 2 above indicate a dry or worn drive mechanism.)

3. Look for loose mounting bolts

4. Remove commutator end frame and check for burned communtator bars, high mica, worn brushes or an oily commutator and brushes

(NOTE: Correct 3 and 4 before further testing, if necessary.)

5. Check pinion gear for freedom of movement by turning shaft

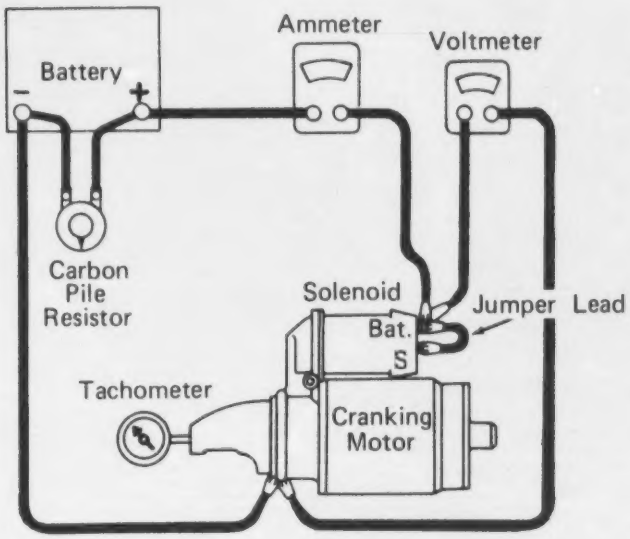
B. Conduct no-load test

1. Remove starter from engine

JOB SHEET #3

2. Connect starter motor to a fully charged battery (Figure 1)

FIGURE 1



3. Connect an ammeter between battery and starting motor (Figure 1)

4. Connect a jumper wire between tne "s" terminal and the battery post so solenoid current draw is not measured, if technical manual specification is for basic motor only (See Figure 1)

5. Connect voltmeter to starting motor terminal and frame (Figure 1)

6. Connect carbon pile resistor across the battery (Figure 1)

7. Place a tachometer on end of armature to measure armature speed (Figure 1)

8. Start motor by connecting leads to battery terminal

9. Vary the carbon pile resistor until the specified voltage is shown on the voltmeter

10. Read the ammeter for the current draw

11. Read the tachometer for the armature speed

12. Compare the readings with the technical manual specifications for the starter motor being tested

JOB SHEET #3

C. Interpret no-load test results

1. Rated current draw and no-load speed indicates a normal starter motor condition

2. Low free speed and high current draw indicate:

   a. Too much friction

   b. Shorted armature

   c. Grounded armature of fields

3. Failure to operate with high current draw indicates:

   a. A direct ground in the terminal or fields

   b. Frozen bearings

4. Failure to operate with no current draw indicates:

   a. Open field circuit

   b. Open armature coils

   c. Broken brush springs, worn brushes or high insulation between commutator bars

5. Low speed and low current draw indicates high internal resistance due to poor connections, dirty commutator, or an open field circuit

6. High free speed and high current draw indicate shorted fields

STARTING CIRCUITS
UNIT III

JOB SHEET #4--RECONDITION STARTING MOTOR ARMATURE

I. Tools and materials

A. Basic hand tool set

B. Special tool for turning commutators or a lathe

C. Special tool for undercutting commutator or hacksaw blade

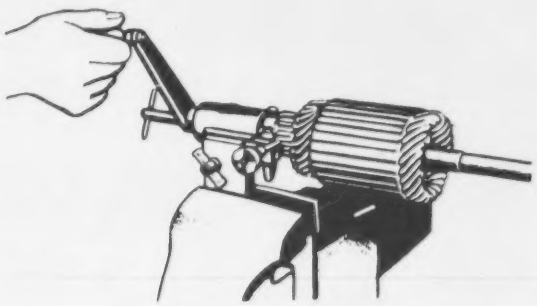
D. Safety glasses

II. Procedure

A. Turn down commutator

1. Secure armature and special tool in vise or lathe (Figure 1)

FIGURE 1



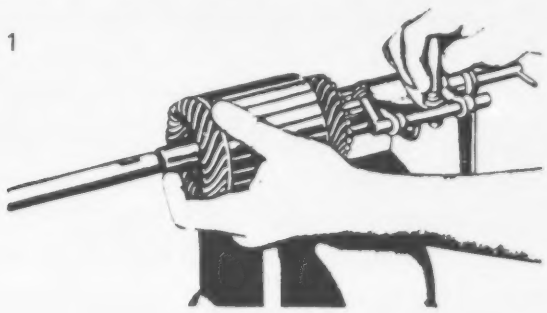
2. Remove only enough metal to "true-up" the commutator

B. Undercut the mica between commutator bars

1. Secure armature and special tool in vise (Figure 1)

(NOTE: Use hacksaw blade saw with same width as distance between commutator bars if special tool is not available.)

FIGURE 1



JOB SHEET #4

2. Undercut mica on commutator

(NOTE: Always consult starting motor specifications before reconditioning armature. Most high output starting motor armatures should not be undercut after the armature is turned down.)

STARTING CIRCUITS
UNIT III

NAME _____

TEST

1. Match the terms on the right to the correct definitions.

_____a.	Ends of a magnet in the field frame assembly of a starting motor	1.	Armature
_____b.	Wire wrapped around pole pieces to increase the strength of the magnetic field when current is passed through the windings	2.	Solenoid
_____c.	Main drive of starter motor; converts electrical energy into mechanical energy	3.	Pinion
_____d.	Metal segments attached to ends of wire loops to form contact surface on armature	4.	Pole pieces
_____e.	Sliding contacts to feed electrical energy from battery to commutator	5.	Field winding
_____f.	Small gear that meshes with a larger gear	6.	Commutator
_____g.	Electromagnetic switch that closes circuit and engages the motor drive pinion with the flywheel	7.	Brushes
_____h.	Manual, magnetic, or solenoid switch	8.	Inertia
_____i.	Tendency of a body in motion to remain in motion	9.	Motor switch
_____j.	Counter electromotive force	10.	CEMF

2. Explain the purpose of the starting circuit.

3. Name four major parts in the starting circuit.

a.

b.

c.

d.

4. Match the major parts on the right to their correct functions.

_____a. Supplies energy for the circuit	1. Motor switch
_____b. Activates the circuit	2. Starter switch
_____c. Closes circuit to motor and engages motor drive with flywheel	3. Starting motor
_____d. Drives flywheel to start engine	4. Battery

5. Name four major parts of a starting motor.

a.

b.

c.

d.

6. Match the component parts of the starting motor on the right to their correct functions.

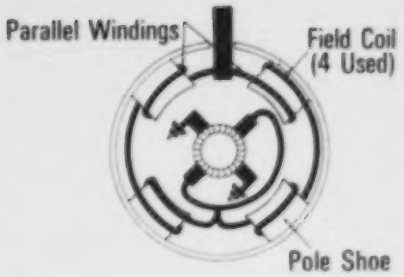
_____a. Forms a magnetic field of force around armature	1. Armature
_____b. Wrapped around pole shoe to strengthen magnetic field when current is passed thorugh the winding	2. Field winding
_____c. Converts electrical energy into mechanical energy to drive mechanism to crank engine	3. Commutator
_____d. Forms contact surface for battery to feed electrical current through armature	4. Brushes
_____e. Sliding contacts which feed electrical energy to the commutator	5. Pole shoe

7. Explain how a basic starting motor converts electrical energy into mechanical energy.

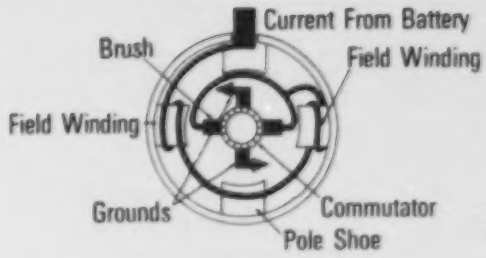
8. Explain how a starting motor is kept running.

9. Discuss the current flow in a starting motor circuit.

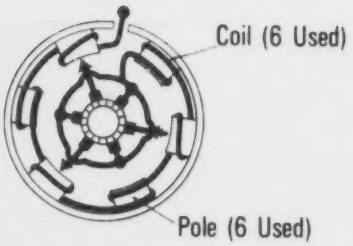
10. Identify four types of starter field circuits.

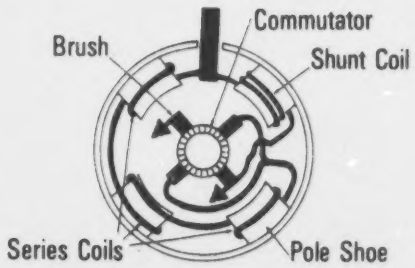


a. _____



b. _____





c. _____ d. _____

11. Match the types of starter field circuits on the right to the current flow in each type circuit.

_____a. Current flows through all the field windings before it flows through the two insulated brushes to the armature	1.	Compound-wound
	2.	Series-wound
_____b. Current flows through one field winding to the brushes, and also through the other field winding to the brushes, placing the field windings in parallel	3.	Series-parallel-wound
	4.	Parallel- wound
_____c. One third of the current flows through each pair of field windings to one of the three insulated brushes		
_____d. One or more of the poles is shunt wound, connected directly to ground to prevent excessive speeds		

12. Discuss counter electromotive force in relation to armature speed.

13. Name four types of switches for starting motors.

a.

b.

c.

d.

14. Distinguish between a magnetic switch and a solenoid switch by placing an "X" next to the description of the magnetic switch.

_____a. Provides a mechanical means of shifting pinion into mesh with flywheel

_____b. Normally used with bendix drive as switch does not provide mechanical shifting of drive mechanism

15. Discuss the operation of the series-parallel switch.

a.

b.

c.

16. Explain two ways starter drives are engaged.

a.

b.

17. List three types of electromagnetic or lever shift drives.

a.

b.

c.

18. Demonstrate the ability to:

a. Remove and replace a starter.

b. Disassemble, test, and reassemble a starter.

c. Test starter circuit (no-load).

d. Recondition starting motor armature.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

STARTING CIRCUITS
UNIT III

ANSWERS TO TEST

1. a. 4
   b. 5
   c. 1
   d. 6
   e. 7
   f. 3
   g. 2
   h. 9
   i. 8
   j. 10

2. Explanation should include:

   Converts electrical energy from the battery into mechanical energy at the starting motor to crank the engine

3. A. Battery
   b. Starter switch
   c. Motor switch
   d. Starting motor

4. a. 4
   b. 2
   c. 1
   d. 3

5. a. Motor switch
   b. Field frame assembly
   c. Armature
   d. Drive mechanism

6. a. 5
   b. 2
   c. 1
   d. 3
   e. 4

7. Explanation should include:

   Current carrying conductor (armature) formed in a loop and mounted on a shaft, will cause the shaft to rotate when placed inside a magnetic field (field windings)

8. Explanation should include:

   a. The magnetic field around the armature and the magnetic field between the pole pieces repel each other causing the armature to turn

   b. Metal segments on the ends of the commutator make a one-half turn reversing their connection through sliding contacts (burshes) which causes the current to flow in the opposite direction in the armature windings

9. Discussion should include--Current will flow from battery, through cable, across switch contacts, through field windings and armature, and back to battery through ground

10. a. Parallel-wound

    b. Series-wound

    c. Series-parallel-wound

    d. Compound-wound

11. a. 2

    b. 4

    c. 3

    d. 1

12. Discussion should include:

    a. Counter voltage (CEMF) is induced into the armature windings when they pass through the magnetic field of the field coils

    b. The faster the armature turns the higher the counter voltage

    c. The compound-wound starter shunt winding prevents excessive speeding because the shunt winding is connected directly to ground, reducing the series wound field winding, armature current flow, and armature free speed

13. a. Manual

    b. Solenoid

c. Magnetic

d. Series-parallel

14. b

15. Discussion should include:

a. Starter switch closes, connecting two 12 volt batteries in series with the starting motor

b. Solenoid circuit is completed by a set of points mechanically closed by the series-parallel switch plunger and starter turns over

c. Starter switch is released, going into neutral position, permitting operation of electrical equipment by two 12 volt batteries in parallel for normal operation

16. Explanation should include:

a. Inertia of armature acting through drive mechanism

b. Electromagnetic plunger to mechanically shift pinion into mesh

17. a. Overrunning clutch

b. Dyer drive

c. Sprag clutch drive

18. Performance skills evaluated to the satisfaction of the instructor

IGNITION CIRCUITS
UNIT IV

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify the components and explain the purpose of the ignition circuit. The student should be able to remove and replace the distributor, install contact points and condenser, and set contact point dwell and ignition timing. The student should also be able to remove, service, and replace spark plugs. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with the ignition circuit to the correct definitions.
2. Explain the purpose of the ignition circuit.
3. Identify the components of the ignition circuit.
4. Match the components of the ignition circuit to the correct functions.
5. Distinguish between primary and secondary ignition circuit components.
6. Identify the components of the distributor.
7. Discuss the operation of the ignition circuit beginning with the battery through one complete cycle.
8. Discuss the transistorized and capacitive discharge ignition systems.
9. Identify the major components of an electronic ignition system.
10. Discuss the functions of the major components of the electronic ignition system.
11. Demonstrate the ability to:
    a. Remove and install a distributor.
    b. Remove and replace contact points and condenser.
    c. Adjust dwell on an externally adjustable distributor.
    d. Check and set ignition timing.
    e. Remove, service, and replace spark plugs.

IGNITION CIRCUITS
UNIT IV

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined in the job sheets.

G. Discuss spark plug heat range.

H. Discuss the different methods of ignition bypass.

I. Give test

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete job sheets.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Components of the Ignition System

2. TM 2--Primary Circuit

3. TM 3--Secondary Circuit
4. TM 4--Distributor Components
5. TM 5--Operation of the Ignition System
6. TM 6--Operation of the Ignition System (Continued)
7. TM 7--Operation of the Ignition System (Continued)
8. TM 8--Operation of the Ignition System (Continued)
9. TM 9--Operation of the Ignition System (Continued)
10. TM 10--Major Components of the Electronic Ignition System

D. Job sheets

1. Job Sheet #1--Remove and Install a Distributor
2. Job Sheet #2--Remove and Replace Contact Points and Condenser
3. Job Sheet #3--Adjust Dwell on an Externally Adjustable Distributor
4. Job Sheet #4--Check and Set Ignition Timing
5. Job Sheet #5--Remove, Service, and Replace Spark Plugs

E. Test

F. Answers to test

II. References:

A. *Fundamentals of Service: Electrical Systems*. Moline, Illinois: Deere and Company.

B. Billiet, Walter E., and Goings, Leslie F. *Automotive Electrical Systems*. 3rd ed. Chicago, Illinois: American Technical Society.

C. Crouse, William H. *Automotive Mechanics*. New York, New York: Webster Division/McGraw-Hill Book Company.

IGNITION CIRCUITS
UNIT IV

INFORMATION SHEET

I. Terms and definitions

A. Timing--Igniting the fuel-air mixture at the exact instant that will enable the engine to develop maximum power

B. Timing marks--Marks used to synchronize the ignition circuit so that plugs will fire at the precise time

(NOTE: Timing marks are usually located on the vibration damper or flywheel.)

C. Primary ignition circuit--Low voltage circuit which energizes the ignition coil

D. Secondary ignition circuit--High voltage circuit which produces electrical current to jump spark plug gap

E. Dwell--Number of degrees of distributor cam rotation that the ignition points are closed

F. Condenser--A unit installed between the breaker points and coil to prevent arcing

(NOTE: A condenser has the ability to absorb and retain surges of electricity.)

G. Coil polarity--A means of connecting the coil primary windings to the distributor so that current produced at the spark plug will travel from center electrode to ground

Example: On negative-ground systems, the negative primary terminal of coil is connected to the distributor. On positive-ground systems, the positive primary terminal is connected to the distributor

H. Electronic ignition system--Ignition system using a control unit and magnetic pickup to open and close the primary circuit

II. Purpose of ignition circuit--The ignition circuit produces a high voltage spark which ignites the fuel air mixture in the engine cylinder

INFORMATION SHEET

III. Components of ignition circuit (Transparency 1)

A. Battery

B. Ignition switch

C. Primary resistance unit

D. Ignition coil

E. Contact points

F. Condenser

G. Distributor

H. Breaker cam

I. Spark-advance mechanism

(NOTE: There are two types of spark-advance mechanisms, vacuum and mechanical. Engine vacuum controls timing advance in relation to engine load. Mechanical advance changes engine timing according to engine speed.)

J. Rotor

K. Distributor cap

L. Spark plug

M. Primary ignition wire

N. Secondary ignition cable

O. Ignition bypass circuit

IV. Components of the ignition circuit and functions (Transparency 1)

A. Battery--Source of electrical power

B. Ignition switch--Opens and closes the primary circuit between battery and contact points

C. Primary resistance unit--Reduces voltage in the primary circuit to protect the contact points

D. Ignition coil--Transforms low voltage into high voltage necessary to jump the spark plug gap

E. Contact points--Make and break the primary circuit to allow the coil to produce high voltage at the spark plugs

INFORMATION SHEET

F. Condenser--Device that absorbs surges in the primary circuit when the opening of the ignition points causes an interruption in current flow

G. Distributor--Contains the contact points and condenser; distributes the high voltage current from the coil to the proper cylinder

H. Breaker cam--Opens and closes the contact points

I. Spark-advance mechanism--Regulates the timing of the high voltage circuit for best ignition during all speed and load conditions

J. Rotor--Takes the high voltage current from the coil and directs it to the correct cylinder

K. Distributor cap--Holds the coil and spark plug wires in a sequence and provides a cover for the distributor

L. Spark plug--Provides a spark gap inside the engine cylinder to ignite the fuel air mixture

M. Primary ignition wire--Carries low voltage from the battery to the primary side of the ignition coil (light wire)

N. Secondary ignition cable--Carries high voltage from the secondary side of the coil to the spark plug (heavily insulated wire)

O. Ignition bypass circuit--Primary ignition circuit that bypasses the ignition resistance unit, permitting full battery voltage to the ignition coil during starting only

V. Ignition circuit components

A. Primary--Low voltage circuit (Transparency 2)

1. Battery
2. Ignition switch
3. Resistance unit
4. Primary winding of the coil
5. Contact points
6. Condenser
7. Low voltage wire that connects the units

INFORMATION SHEET

B. Secondary--High voltage circuit (Transparency 3)

1. Secondary winding of the coil
2. Distributor cap
3. Rotor
4. Spark plug
5. High voltage wire that connects the units

VI. Distributor components (Transparency 4)

A. Distributor cap

B. Rotor

C. Centrifugal advance mechanism

D. Condenser

E. Vacuum advance unit

F. Breaker plate

G. Distributor cam

H. Contact points

I. Distributor housing

J. Primary lead wire

K. Distributor drive gear

VII. Operation of the ignition circuit

A. With the ignition switch on and the contact points closed, low voltage current flows from the battery through the primary winding of the coil and through the contact points to ground (Transparency 5)

B. The flow of low voltage current through the primary windings of the coil causes a magnetic field buildup (Transparency 6)

C. As the contact points open, current attempts to flow across the point surfaces; the condenser attached to the points absorbs this flow of current (Transparency 7)

INFORMATION SHEET

D. Stopping this flow of current causes the magnetic field of the coil to collapse across the secondary coil windings, causing a high voltage surge (Transparency 8)

E. This high voltage surge is directed from the secondary windings of the coil through the distributor cap and rotor and on to the spark plug to ground (Transparency 9)

VIII. Transistorized and capacitive discharge ignition systems

A. Both variations designed to increase primary voltage to coil and reduce voltage to points or eliminate points

B. Transistorized ignitions

1. Amplifier included in circuit between points and ignition coil

2. Transistors allow very low voltage through the points and very high voltage to the primary windings in coil

C. Capacitive discharge system

1. System contains special ignition distributor, amplifier, and special coil

2. System operates to charge a capacitor to a high voltage which, on signal from distributor, is then discharged through the primary windings in coil

IX. Major components of the electronic ignition system (Transparency 10)

A. Dual ballast resistor

(NOTE: This component is not used on all models.)

B. Control unit

C. Magnetic pickup assembly

D. Armature or reluctor

X. Function of the major components of the electronic ignition system

A. Dual ballast resistor--Maintains constant primary current with variations in engine speed

(NOTE: The dual ballast resistor is bypassed during engine starting.)

INFORMATION SHEET

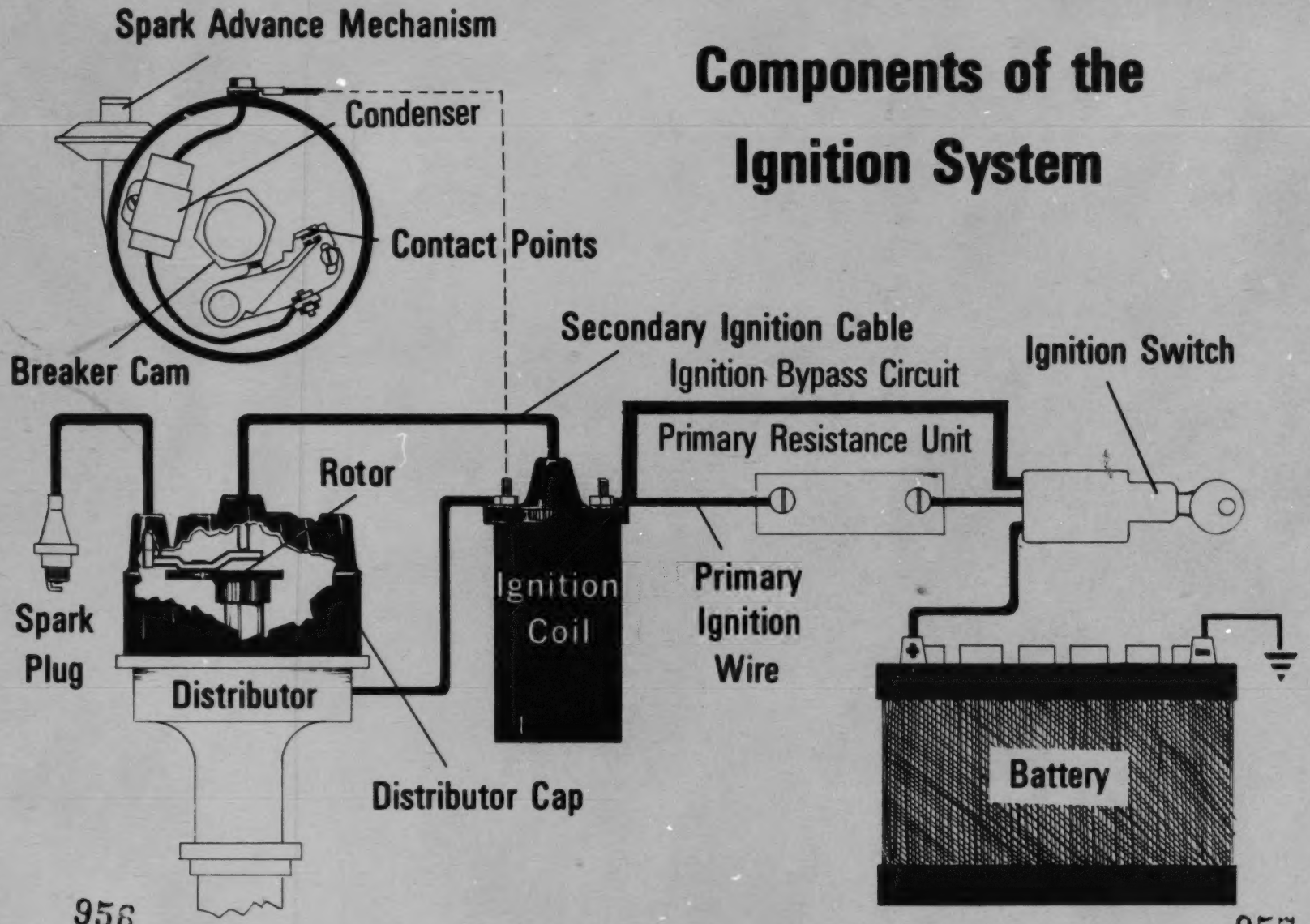
B. Magnetic pickup assembly--Sends a small voltage pulse to the control unit to trigger switching transistor to stop current flow in the coil primary windings

C. Armature or reluctor--Rotates with the distributor shaft, producing a voltage pulse in the magnetic pickup

(NOTE: The armature contains the same number of tips as the engine contains cylinders.)

D. Control unit--Controls the flow of current in the primary windings of the ignition coil and maintains constant dwell

Components of the Ignition System



TM 1

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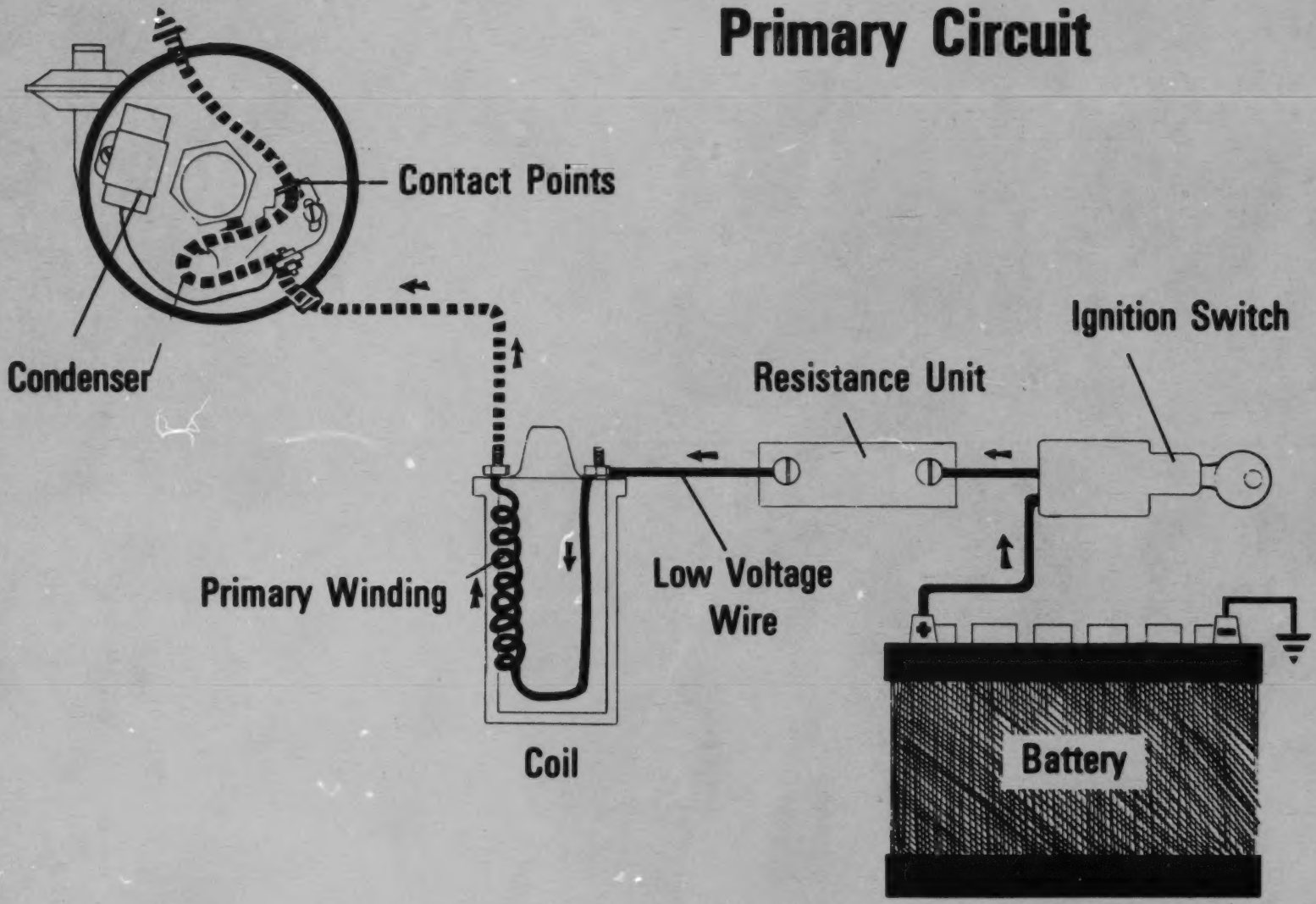
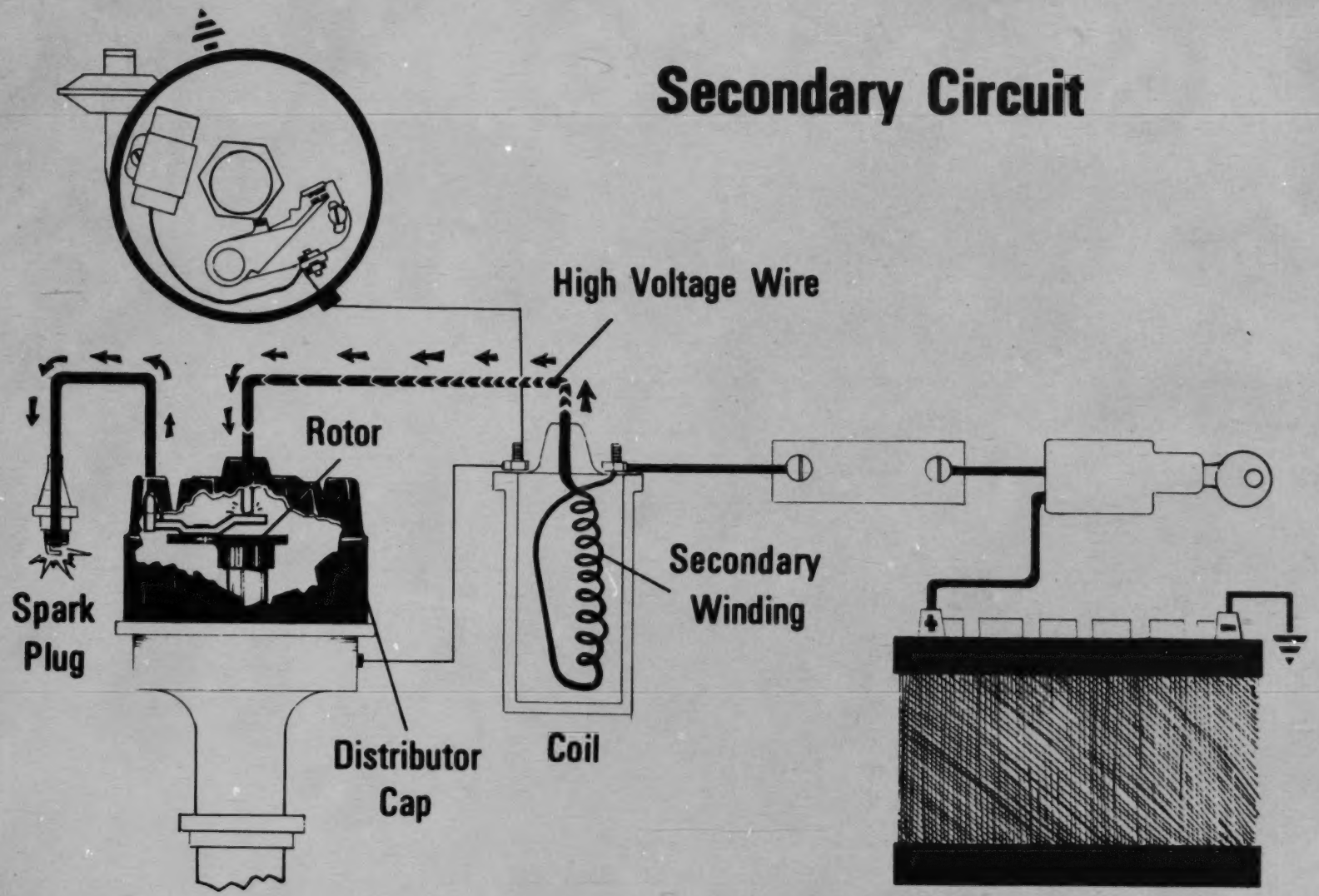
Primary Circuit



Secondary Circuit



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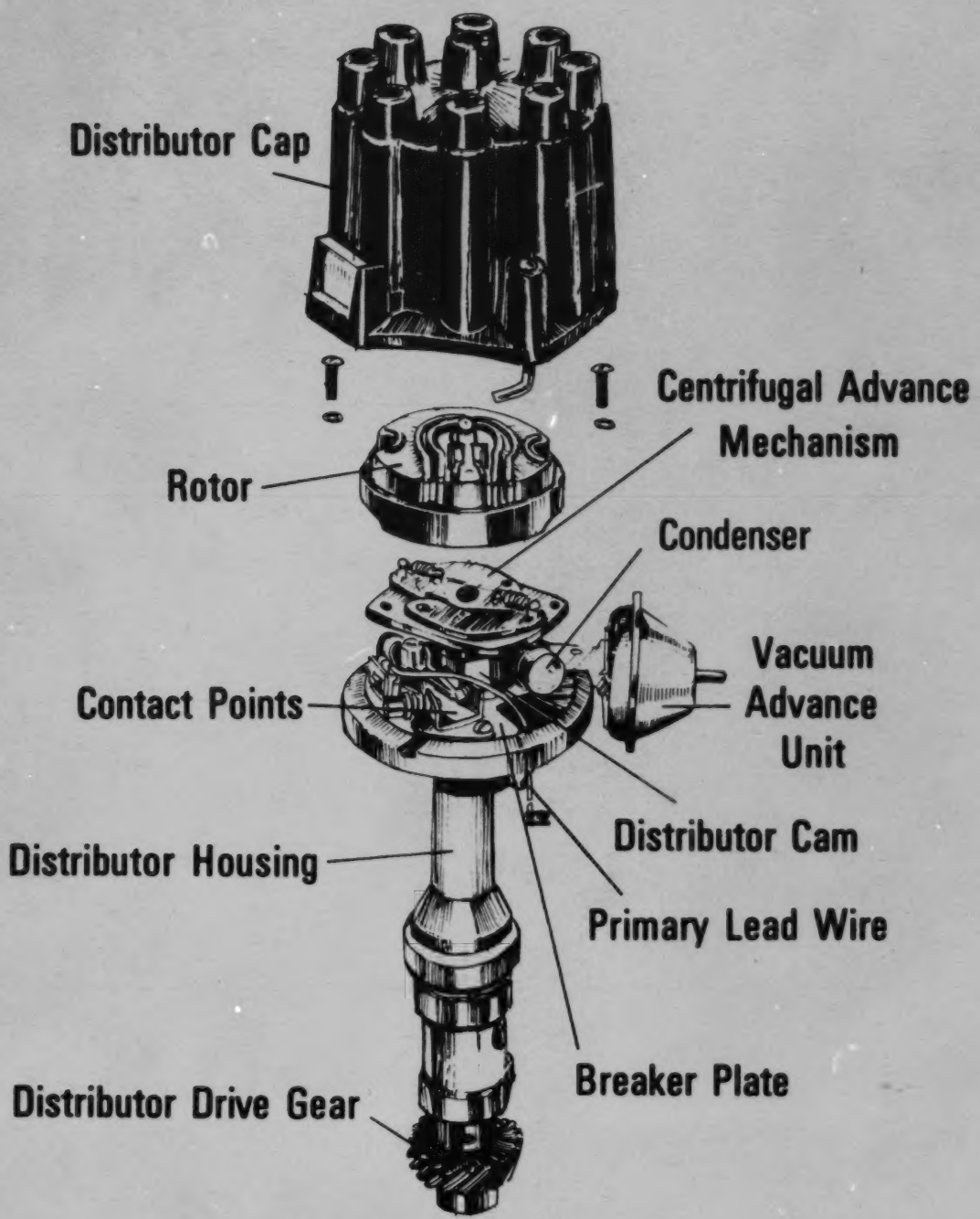
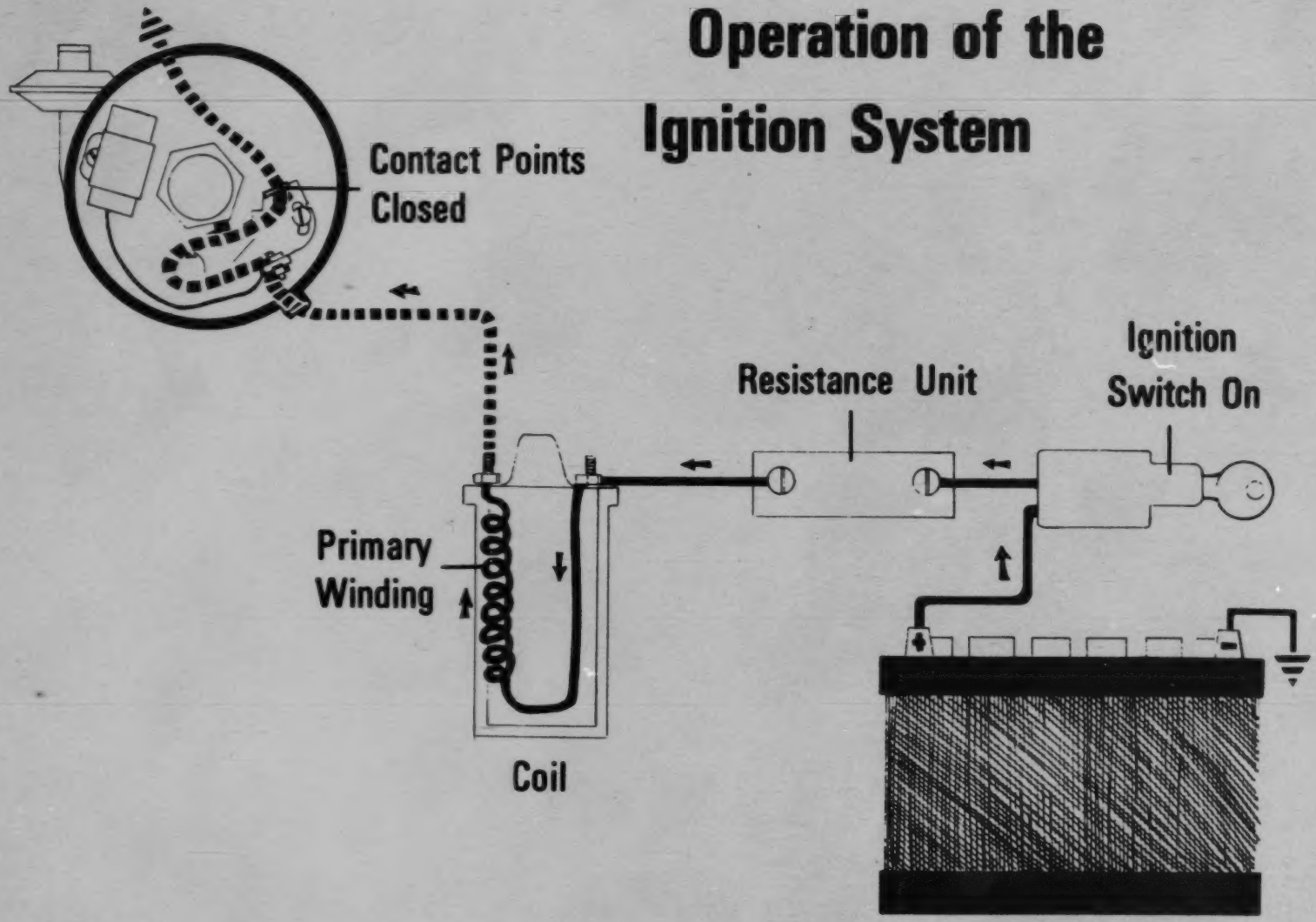
Distributor Components



Operation of the Ignition System



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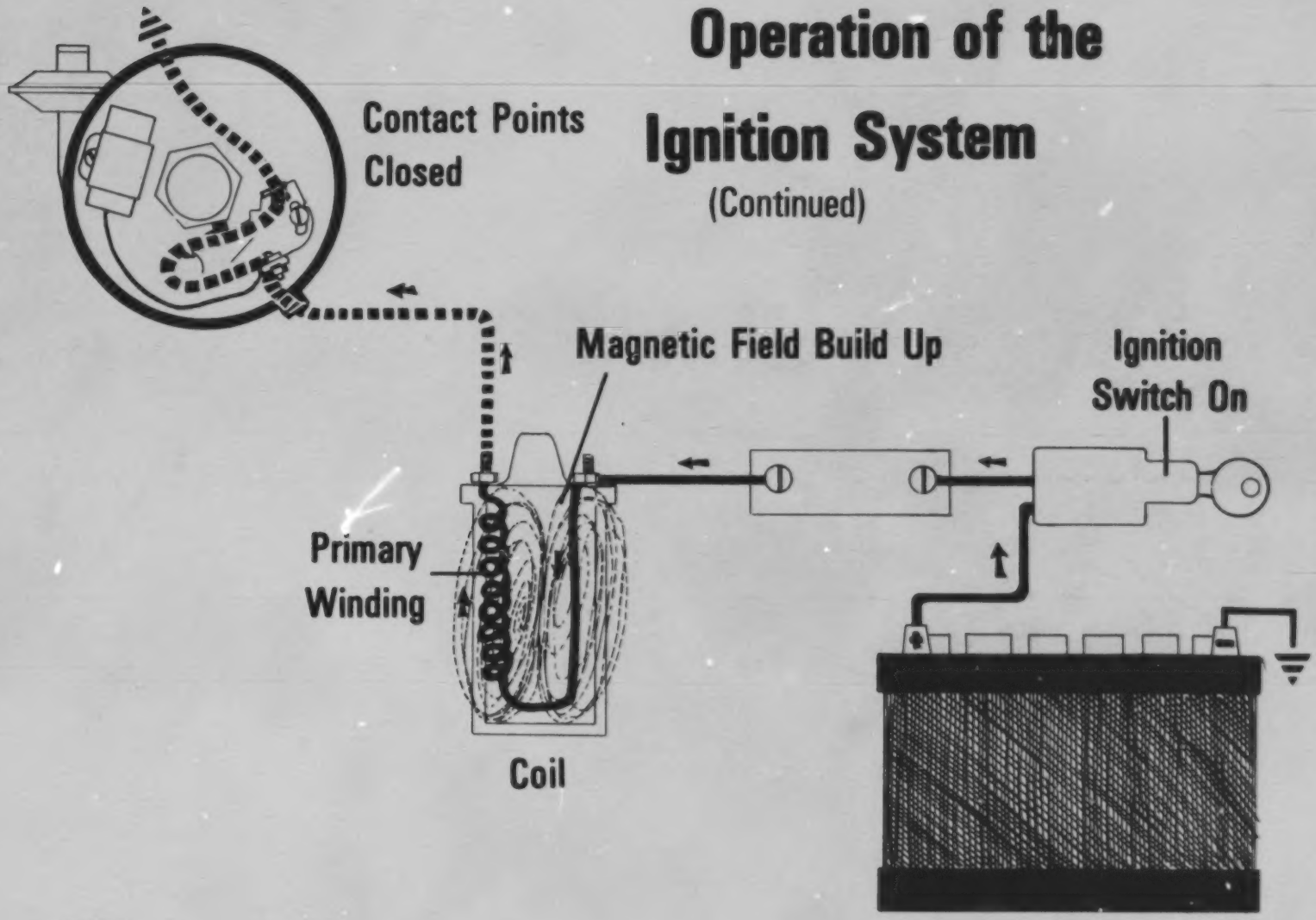
Operation of the Ignition System
(Continued)



Operation of the Ignition System
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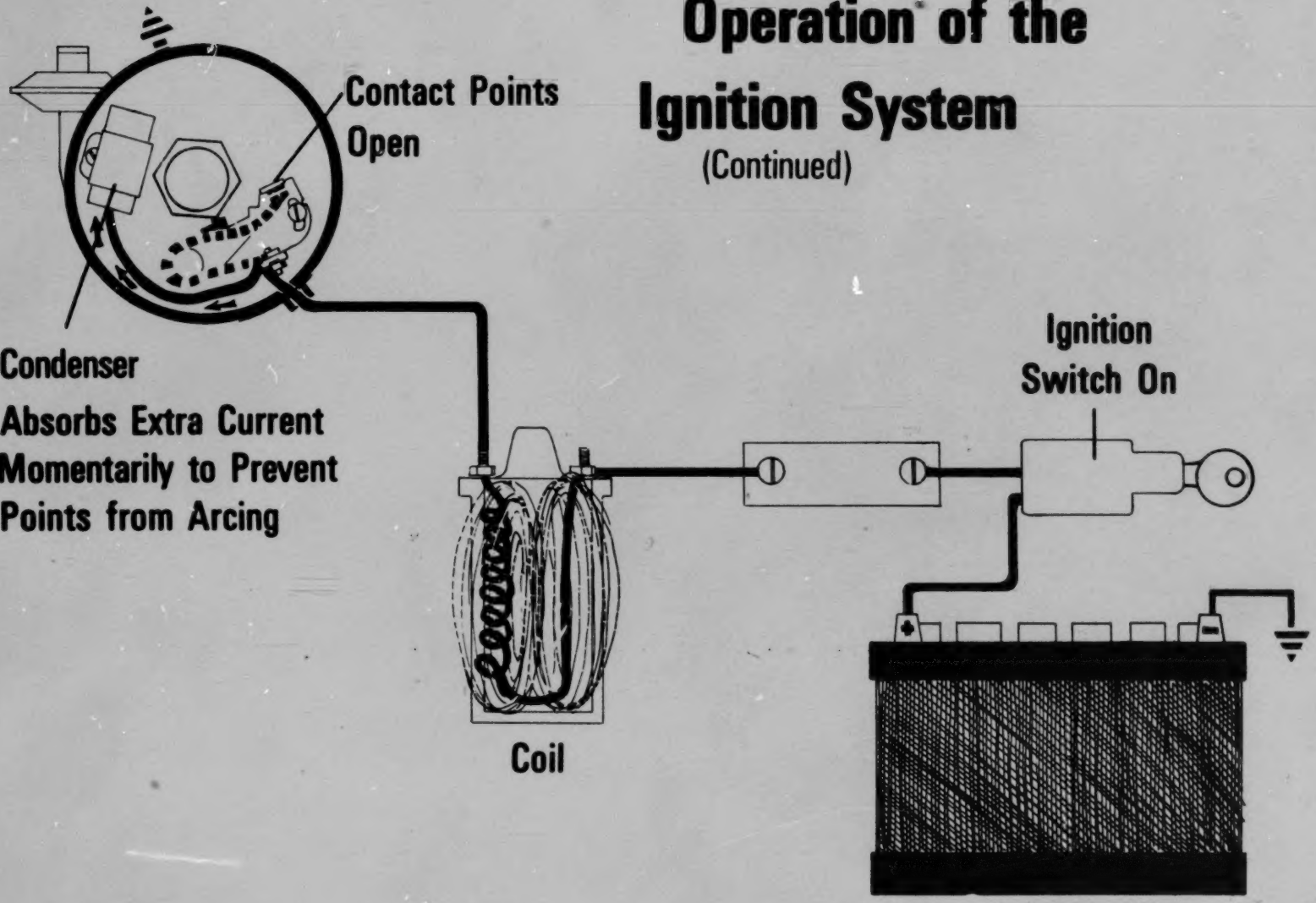

Operation of the Ignition System
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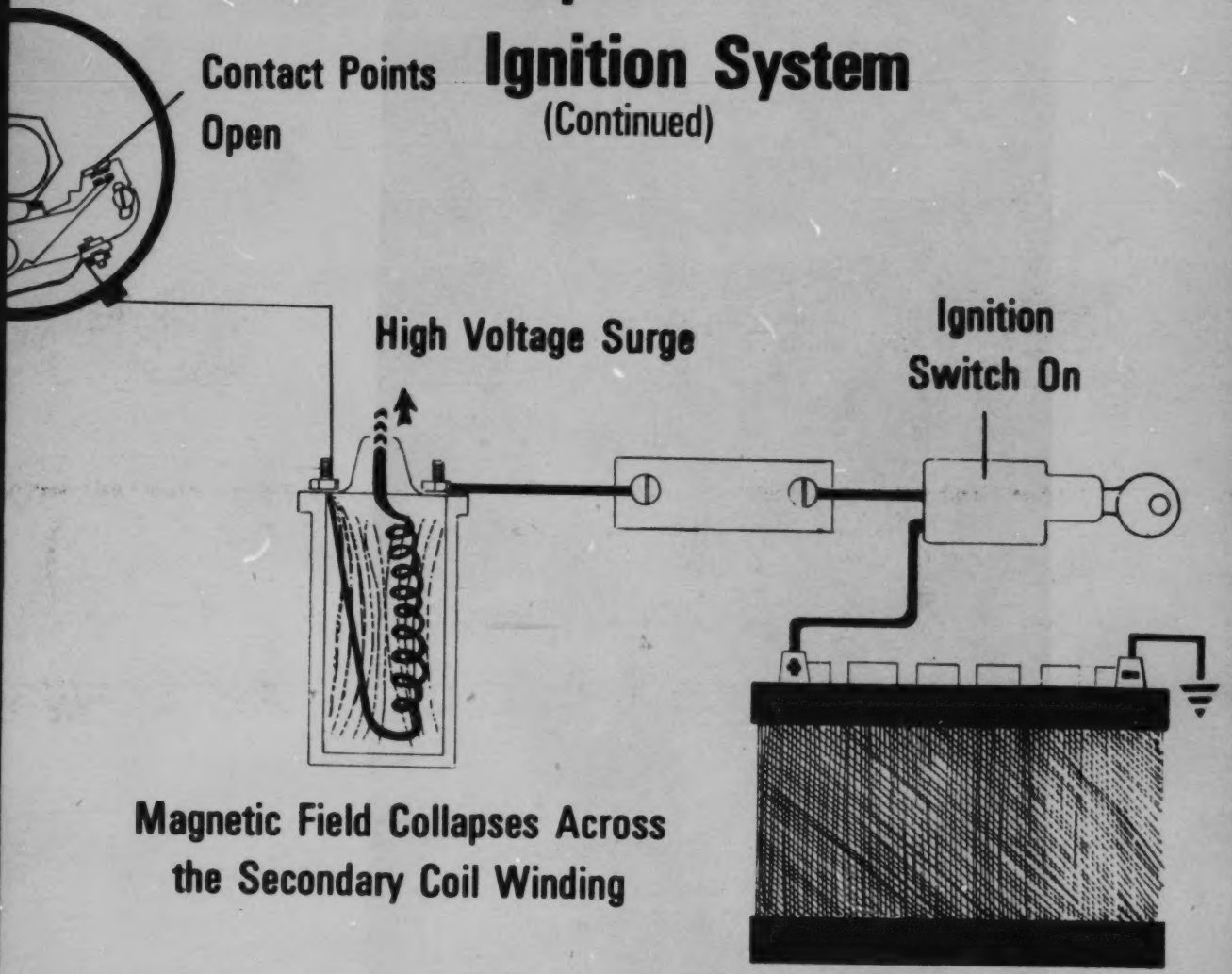
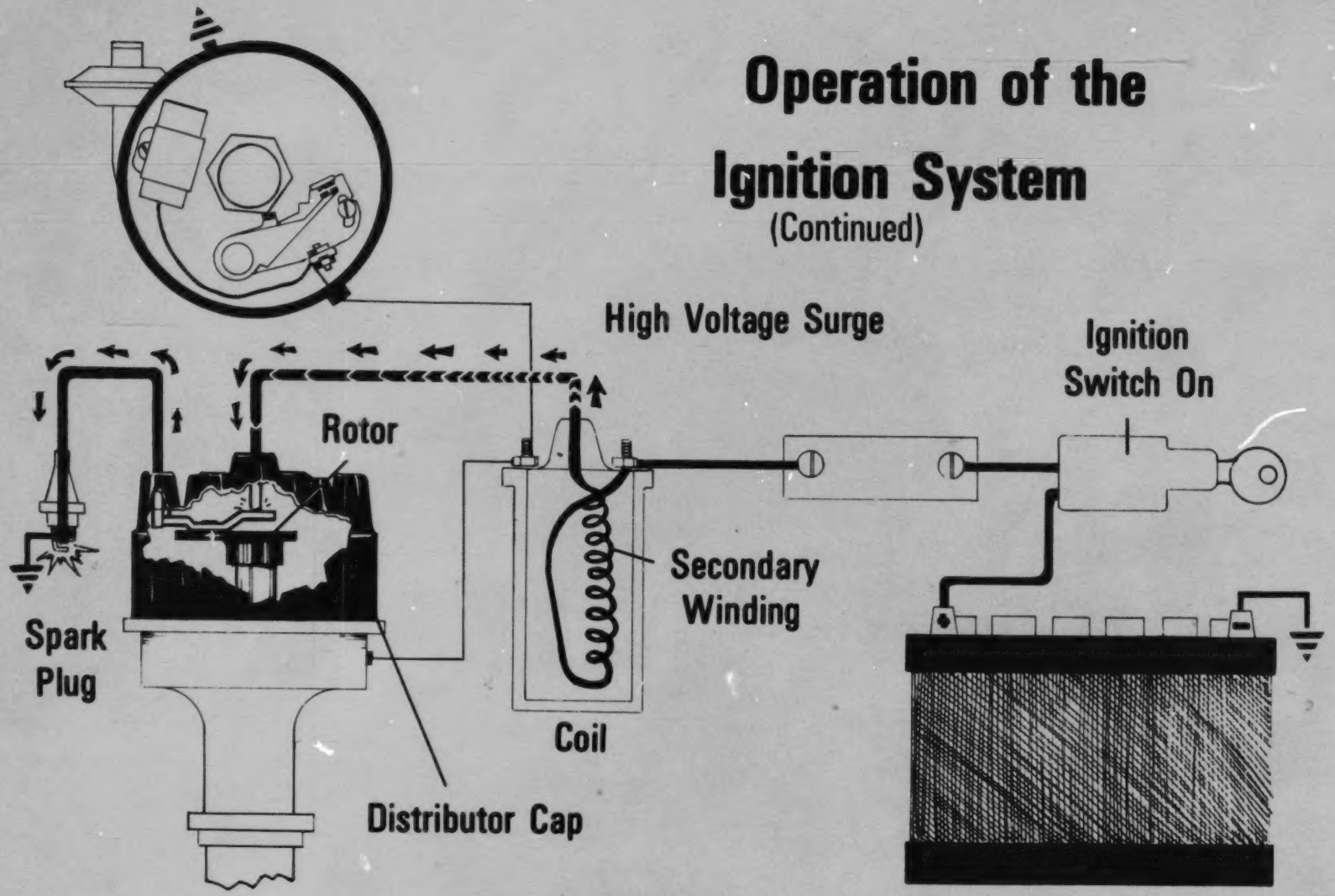


Operation of the Ignition System
(Continued)



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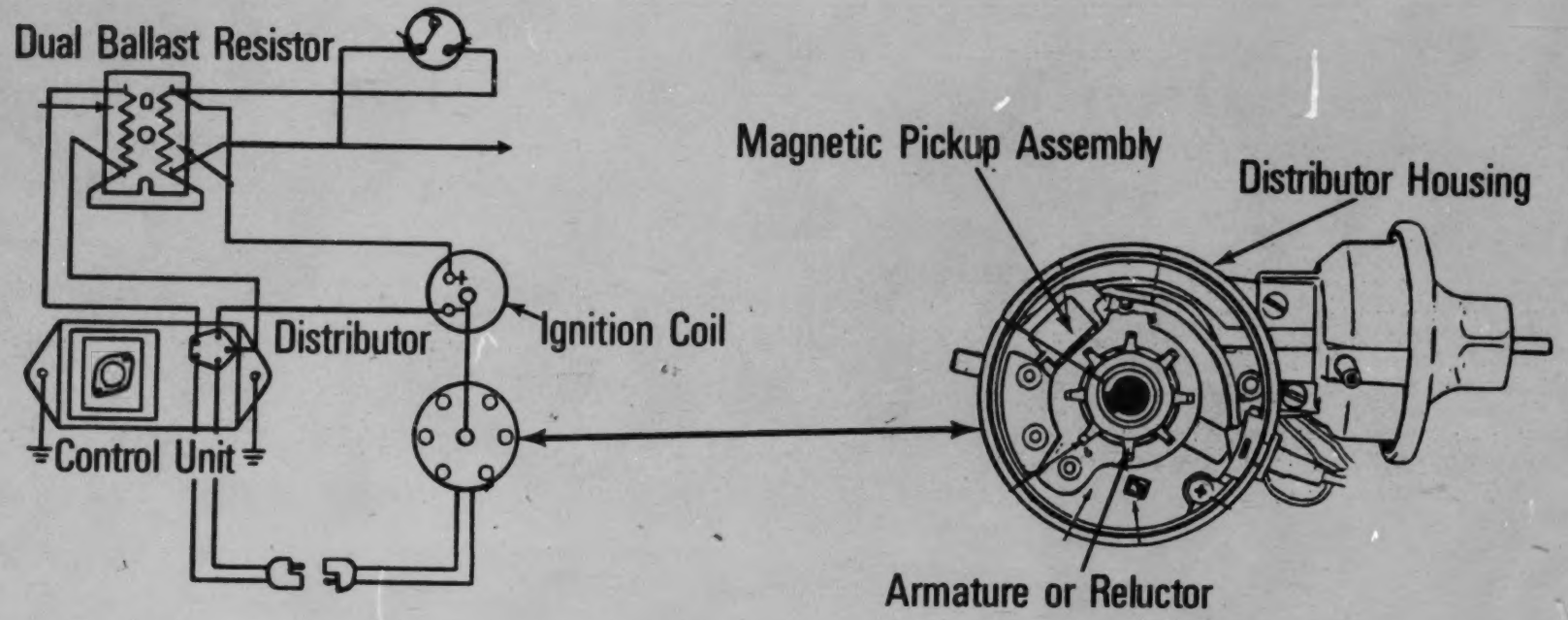
Major Components of the Electronic Ignition System



IGNITION CIRCUITS
UNIT IV

JOB SHEET #1--REMOVE AND INSTALL A DISTRIBUTOR

I. Tools and materials

A. Basic hand tool set

B. Set of ignition wrenches

C. Special distributor wrenches as required

D. Auxiliary starter button

E. Spark plug socket wrench

F. Shop towels

G. Safety glasses

II. Procedure

A. Remove distributor

1. Remove air cleaner if required

2. Remove the distributor wire from coil or distributor as required

3. Remove the distributor cap and position out of the way

4. Mark position of the rotor

(NOTE: It is necessary that the position be marked or indicated in some manner for re-installation.)

5. Remove vacuum hose line from distributor

JOB SHEET #1

6. Remove distributor clamp screw and hold-down clamp (Figure 1)

FIGURE 1

REMOVE THIS CLAMP

7. Pull distributor up slowly and check direction the rotor turns

   (NOTE: The amount the rotor turns and the direction it turns will be necessary for re-installation.)

8. Remove distributor from engine

   (CAUTION: Avoid dropping bolts, brackets, or foreign material into opening. Cover with a shop towel.)

9. Service distributor as required

B. Install distributor

1. Remove number one cylinder spark plug

2. Install auxillary starter button and crank the engine until compression is felt on number one cylinder

3. Crank the engine with short movements until the timing marks on the flywheel indexes with the timing marks on the front cover (Figure 2)

FIGURE 2

JOB SHEET #1

4. Place distributor in opening

   (NOTE: The rotor must be pointing in the same direction as it was before removal.)

5. The distributor may have to be moved around to engage the oil pump shaft

   (NOTE: Occasionally the distributor will not fall into place because the oil pump shaft has moved. The rotor should be positioned as close as possible to the beginning location and the engine rotated slightly until it falls into place. Some distributor drives will be driven by oil pump and gear mesh will not be necessary)

6. Install hold-down clamp and clamp screw

7. Static time point openings

   (NOTE: A connection between distributor side of coil and ground with a light or buzzer can be used.)

8. Tighten the hold-down screw slightly

9. Replace vacuum lines

10. Replace distributor cap and wires if removed

11. Replace spark plugs and plug wires

12. Replace distributor lead wire

13. Check all connections for correct placement

14. Start engine and check timing

15. Check operation of automatic advance

IGNITION CIRCUITS
UNIT IV

JOB SHEET #2--REMOVE AND REPLACE CONTACT POINTS AND CONDENSER

I. Tools and materials

A. Basic hand tool set

B. Ignition wrenches

C. Feeler gauges, .010 - .025

D. Distributor cam lubricant

E. Point alignment tools

F. Timing light

G. Shop towel

H. Safety glasses

II. Procedure

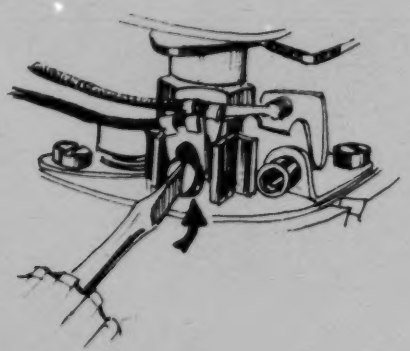
A. Remove distributor cap and place out of the way

B. Remove rotor

C. Determine condition of contact points and location of wires, screws, and eccentric as used

D. Disconnect contact point primary lead wire and condenser wire by loosening screw (Figure 1)

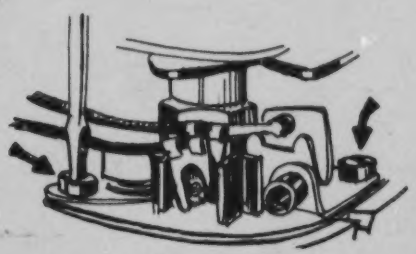
FIGURE 1



JOB SHEET #2

E. Loosen screws holding contact points in place (Figure 2)

FIGURE 2



F. Remove contact point set

G. Remove screw holding condenser in place

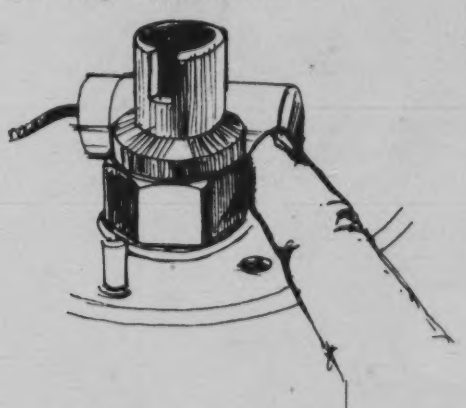
H. Remove condenser

I. Clean breaker plate and distributor cam

J. Lubricate the distributor cam with a light coat of cam lubricant (Figure 3)

(NOTE: On distributors with the centrifugal weights accessible, place a drop of light oil on each weight pivot post.)

FIGURE 3



LUBRICATE DISTRIBUTOR CAM

K. Place the contact points in distributor and install attaching screws

L. Replace condenser and attaching screw; tighten securely

JOB SHEET #2

M. Replace the primary lead and condenser wires

(NOTE: Position the wires in such a manner to avoid binding or grounding.)

N. Tighten primary lead and condenser wires securely

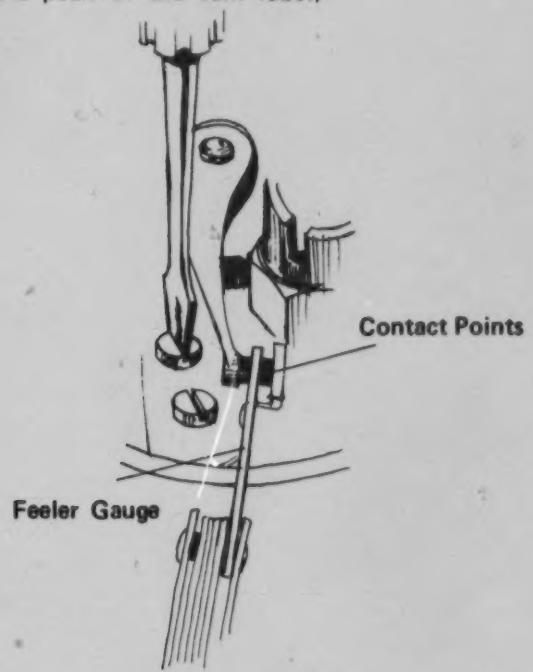
O. Check point alignment and adjust as required

P. Check contact point breaker spring tension

Q. Adjust contact point opening (Figure 4)

(NOTE: Crank the engine to position the rubbing block of the contact points on the peak of the cam lobe.)

FIGURE 4



ADJUST CONTACT POINT OPENING

R. Adjust contact points to manufacturer's recommendations

S. Tighten contact point attaching screws securely; recheck contact point opening

T. Install rotor

(NOTE: Make sure the rotor is positioned correctly and securely in place.)

JOB SHEET #2

U. Install distributor cap

(NOTE: Make sure the distributor is positioned correctly and securely in place.)

V. Replace distributor in engine, if removed

W. Start engine

X. Set timing to manufacturer's specification (Figure 5)

FIGURE 5

TIMING

IGNITION CIRCUITS
UNIT IV

JOB SHEET #3--ADJUST DWELL ON AN EXTERNALLY ADJUSTABLE DISTRIBUTOR

I. Tools and materials

A. Dwell meter

B. Hex contact point adjusting tool

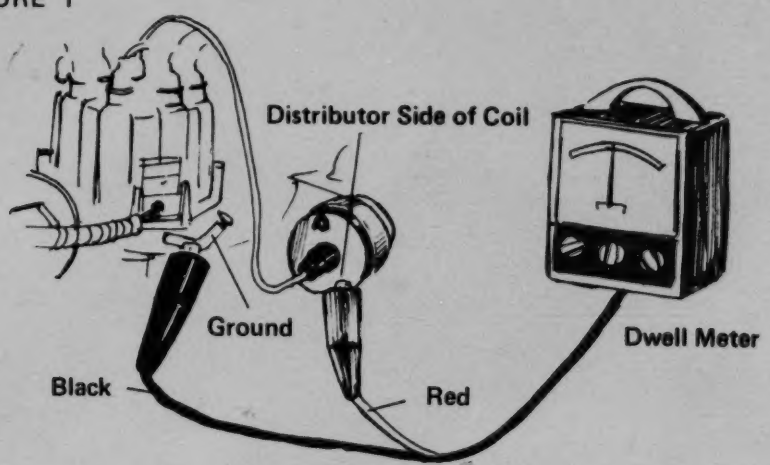
C. Safety glasses

II. Procedure

A. Connect dwell meter (Figure 1)

(CAUTION: Observe correct hookup procedures and position wires away from moving engine parts.)

FIGURE 1



(NOTE: Be sure and disconnect vacuum line.)

B. Refer to manufacturer's specifications for desired dwell setting

C. Start the engine

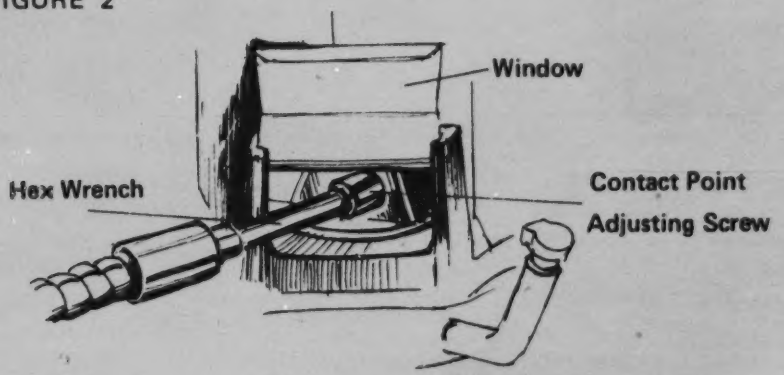
D. Adjust idle speed to manufacturer's specification

E. Raise distributor cap adjustment window

JOB SHEET #3

F. Insert hex wrench into contact point adjustment screw (Figure 2)

FIGURE 2



G. Adjust contact point dwell while observing dwell meter reading to comply with manufacturer's specifications

(NOTE: Recheck engine idle speed.)

H. Remove hex wrench and recheck dwell reading

I. Shut off the engine

J. Remove dwell meter

K. Push window on distributor cap down securely

(NOTE: Replace vacuum line to distributor.)

IGNITION CIRCUITS
UNIT IV

JOB SHEET #4--CHECK AND SET IGNITION TIMING

I. Tools and materials

A. Timing light

B. Combination end wrenches, 7/16" - 9/16"

C. Special distributor wrenches as required

D. Chalk

E. Shop towels

F. Safety glasses

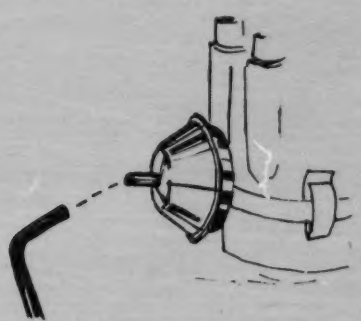
II. Procedure

A. Obtain manufacturer's specifications for ignition timing, dwell, and rpm

(NOTE: RPM and dwell must be set to manufacturer's specifications before timing is set.)

B. Remove vacuum line at the distributor (Figure 1)

FIGURE 1



REMOVE VACUUM LINE

C. Locate and clean the ignition timing marks on the harmonic balancer; mark with chalk

D. Locate and clean the timing pointer or plate on the front cover

E. Connect the timing light according to the instructions for the light being used

(NOTE: Do not puncture spark plug cables with pins or clips to make connections.)

JOB SHEET #4

F. Position wires away from moving engine parts

G. Start the engine

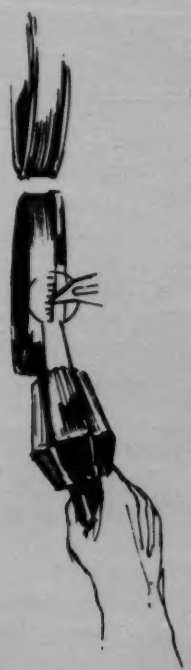
H. Make sure the engine is idling at manufacturer's recommendations

(NOTE: The engine must idle correctly to prevent incorrect timing caused by the centrifugal advance.)

I. Direct the timing light toward the timing marks (Figure 2)

(NOTE: If the timing is correct, the timing marks will line up at the check point. If the timing is incorrect, proceed as follows.)

FIGURE 2



CHECK TIMING

J. Loosen the clamp or lock screw on the distributor

JOB SHEET #4

K. Move the distributor until the timing marks are lined up (Figure 3)

FIGURE 3

MOVE DISTRIBUTOR TO ADJUST TIMING

L. Tighten the clamp or lock screw on the distributor

M. Recheck timing

N. Shut off engine

O. Disconnect timing light

(NOTE: Remove timing light adapter on spark plug if used.)

P. Replace vacuum line on distributor

IGNITION CIRCUITS
UNIT IV

JOB SHEET #5--REMOVE, SERVICE, AND REPLACE SPARK PLUGS

I. Tools and materials

A. Spark plug socket, 3/8" drive

B. Ratchet, 3/8" drive

C. Extensions, 3" - 6" - 10" by 3/8" drive

D. Spark plug cleaner

E. Wire brush

F. Small point file

G. Shop towels

H. Safety glasses

II. Procedure

A. Remove spark plug wires

(NOTE: Pull the wire from the spark plug by grasping the terminal, not by pulling on the wire.)

B. Loosen the spark plugs

C. Clean the area around the spark plug by blowing, wiping, or brushing (Figure 1)

(NOTE: Protect your eyes when using compressed air.)

FIGURE 1

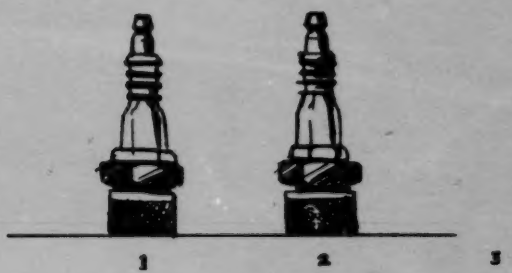
CLEAN AROUND
SPARK PLUG

JOB SHEET #5

D. Remove the spark plugs

(NOTE: Arrange the spark plugs in order as they are removed. The condition of the spark plug can tell a lot about the operation of a particular cylinder. See Figure 2.)

FIGURE 2



ARRANGE IN ORDER

E. Remove the spark plug gaskets if used

F. Determine the condition of the spark plugs and decide whether to replace or service

G. Service by cleaning the spark plugs on a spark plug cleaning machine (Figure 3)

FIGURE 3

CLEAN SPARK PLUGS

JOB SHEET #5

H. Clean the threads with a wire hand brush (Figure 4)

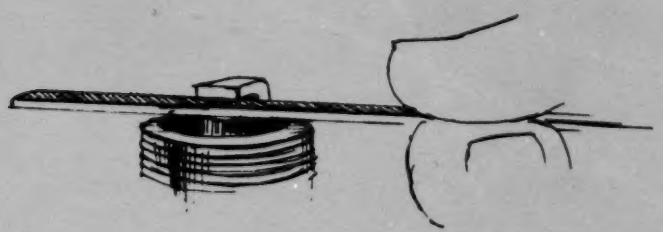
FIGURE 4

CLEAN SPARK PLUG THREADS

I. Bend the ground electrode slightly to open gap

J. File the center electrode to flatten the surface and square up the edges (Figure 5)

FIGURE 5



FILE CENTER ELECTRODE FLAT

JOB SHEET #5

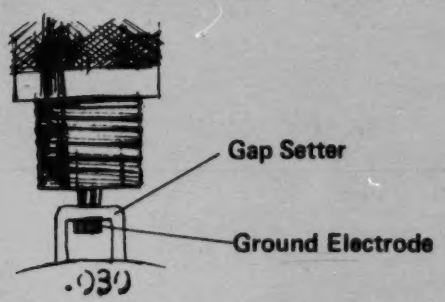
K. Reset gap on new and serviced spark plugs to manufacturer's specifications (Figure 6)

(NOTE: Use a wire gauge to check the gap. Make sure the electrode surfaces are parallel. Regap everytime plugs are serviced.)

(CAUTION: Bend only the ground electrode.)

FIGURE 6

RESET SPARK PLUG GAP



L. Install new spark plug gaskets as required

M. Install spark plugs and tighten

(NOTE: Use caution when starting the spark plugs to avoid cross threading.)

N. Torque the spark plugs to manufacturer's recommendations

O. Replace the spark plug wires in the proper order

(NOTE: Push the spark plug wires securely into place and make sure they are in the brackets or holders.)

IGNITION CIRCUITS
UNIT IV

NAME_____

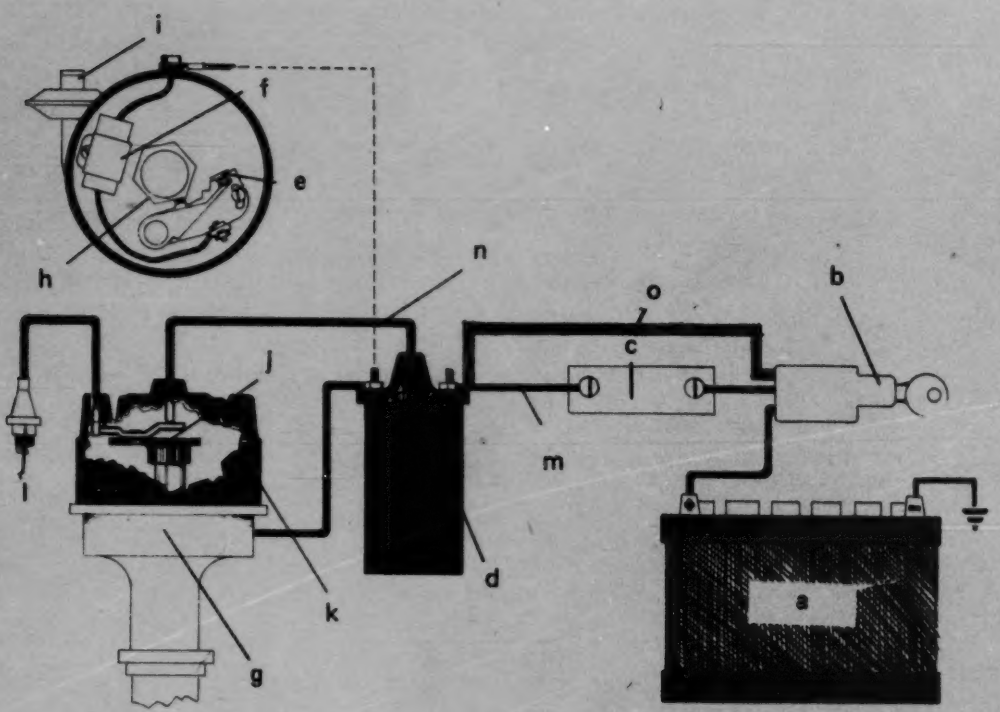
TEST

1. Match terms on the right to the correct definitions.

_____a.	Igniting the fuel-air mixture at the exact instant that will enable the engine to develop maximum power	1. Condenser
_____b.	Marks used to synchronize the ignition circuit so that plugs will fire at the precise time	2. Timing marks
_____c.	Low voltage circuit which energizes the ignition coil	3. Electronic ignition system
_____d.	High voltage circuit which produces electrial current to jump spark plug gap	4. Secondary ignition circuit
_____e.	Number of degrees of distributor cam rotation that the ignition points are closed	5. Dwell
_____f.	A unit installed between the breaker points and coil to prevent arcing	6. Timing
_____g.	A means of connecting the coil primary windings to the distributor so that current produced at the spark plug will travel from center electrode to ground	7. Primary ignition circuit
_____h.	Ignition system using a control unit and magnetic pickup to open and close the primary circuit	8. Coil polarity

2. Explain the purpose of the ignition circuit.

3. Identify the components of the ignition circuit.



a. _____

b. _____

c. _____

d. _____

e. _____

f. _____

g. _____

h. _____

i. _____

j. _____

k. _____

l. _____

m. _____

n. _____

o. _____

4. Match the components of the ignition circuit on the right to the correct functions.

_____a. Source of electrical power

_____b. Opens and closes the primary circuit between battery and contact points

_____c. Reduces voltage in the primary circuit to protect the contact points

_____d. Transforms low voltage into high voltage necessary to jump the spark plug gap

_____e. Make and break the primary circuit to allow the coil to produce high voltage at the spark plugs

_____f. Device that absorbs surges in the primary circuit when the opening of the ignition points causes an interruption in current flow.

_____g. Contains the contact points and condenser; distributes the high voltage current from the coil to the proper cylinder

_____h. Opens and closes the contact points

_____i. Regulates the timing of the high voltage circuit for best ignition during all speed and load conditions

_____j. Takes the high voltage current from the coil and directs it to the correct cylinder

_____k. Holds the coil and spark plug wires in a sequence and provides a cover for the distributor

_____l. Provides a spark gap inside the engine cylinder to ignite the fuel air mixture

_____m. Carries low voltage from the battery to the primary side of the ignition coil (light wire)

1. Ignition switch
2. Primary resistance unit
3. Spark plug
4. Primary ignition wire
5. Breaker cam
6. Distributor
7. Secondary ignition cable
8. Distributor cap
9. Spark-advance mechanism
10. Condenser
11. Ignition coil
12. Rotor
13. Contact points
14. Battery
15. Ignition bypass circuit

_____n. Carries high voltage from the secondary side of the coil to the spark plug (heavily insulated wire)

_____o. Primary ignition circuit that bypasses the ignition resistance unit, permitting full battery voltage to the ignition coil during starting only

5. Distinguish between primary and secondary ignition circuit components by placing a "P" next to primary components and an "S" next to secondary components.

_____a. Resistance unit

_____b. Condenser

_____c. Distributor cap

_____d. Ignition switch

_____e. Rotor

_____f. Secondary winding of the coil

_____g. High voltage wire that connects the units

_____h. Low voltage wire that connects the units

_____i. Contact points

_____j. Battery

_____k. Primary winding of the coil

_____l. Spark plug

6. Identify the components of the distributor.

a. _____

b. _____

c. _____

d. _____

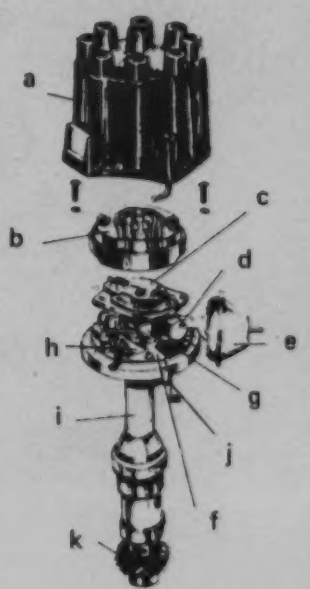
e. _____

f. _____

g. _____

h. _____

i. _____



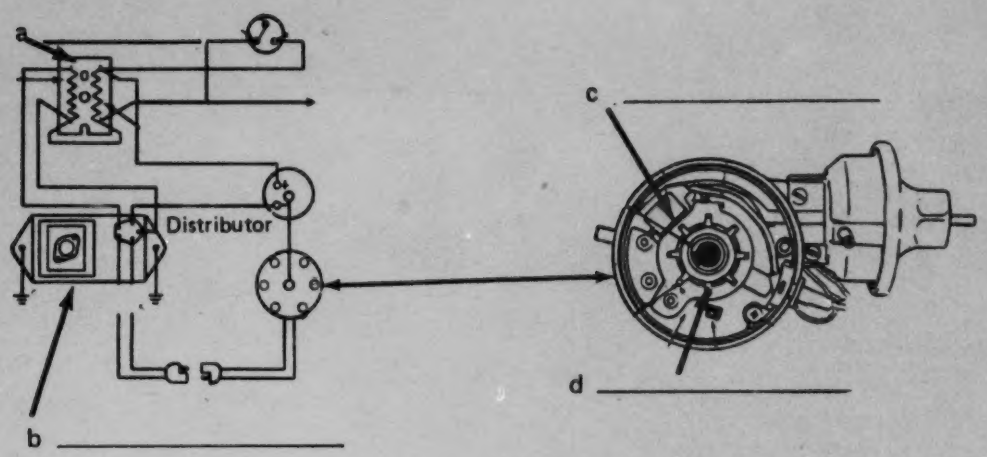
j. _____

k. _____

7. Discuss the operation of the ignition circuit beginning with the battery through one complete cycle.

8. Discuss the transistorized and capacitive discharge ignition systems.

9. Identify the major components of the electronic ignition system.



10. Discuss the functions of the major components of the electronic ignition system.

a. Dual ballast resistor

b. Magnetic pickup assembly

c. Armature or reluctor

d. Control unit

11. Demonstrate the ability to:

a. Remove and install a distributor.

b. Remove and replace contact points and condenser.

c. Adjust dwell on an externally adjustable distributor.

d. Check and set ignition timing.

e. Remove, service, and replace spark plugs.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

IGNITION CIRCUITS
UNIT IV

ANSWERS TO TEST

1.
a.	6	d.	4	g.	8
b.	2	e.	5	h.	3
c.	7	f.	1		

2. Explanation should include--The ignition circuit produces a high voltage current which ignites the fuel air mixture in the engine cylinder

3.
a. Battery
b. Ignition switch
c. Primary resistance unit
d. Ignition coil
e. Contact points
f. Condenser
g. Distributor
h. Breaker cam
i. Spark-advance mechanism
j. Rotor
k. Distributor cap
l. Spark plug
m. Primary ignition wire
n. Secondary ignition cable
o. Ignition bypass circuit

4.
a.	14	f.	10	k.	8
b.	1	g.	6	l.	3
c.	2	h.	5	m.	4
d.	11	i.	9	n.	7
e.	13	j.	12	o.	15

5.

a.	P	e.	S	i.	P
b.	P	f.	S	j.	P
c.	S	g.	S	k.	P
d.	P	h.	P	l.	S

6. a. Distributor cap

   b. Rotor

   c. Centrifugal advance mechanism

   d. Condenser

   e. Vacuum advance unit

   f. Breaker plate

   g. Distributor cam

   h. Contact points

   i. Distributor housing

   j. Primary lead wire

   k. Distributor drive gear

7. Discussion should include:

   a. With the ignition switch on and the contact points closed, low voltage current flows from the battery through the primary winding of the coil and through the contact points to ground

   b. The flow of low voltage current through the primary windings of the coil causes a magnetic field buildup

   c. As the contact points open, current attempts to flow across the point surfaces; the condenser attached to the points absorbs this flow of current

   d. Stopping this flow of current causes the magnetic field of the coil to collapse across the secondary coil windings, causing a high voltage surge

   e. This high voltage surge is directed from the secondary windings of the coil through the distributor cap and rotor and on to the spark plug to ground

8. Discussion should include:

   a. Both variations designed to increase primary voltage to coil and reduce voltage to points or eliminate points

   b. Transistorized ignitions

      1) Amplifier included in circuit between points and ignition coil

      2) Transistors allow very low voltage through the points and very high voltage to the primary windings in coil

   c. Capacitive discharge system

      1) System contains special ignition distributor, amplifier, and special coil

      2) System operates to charge a capacitor to a high voltage which, on signal from distributor, is then discharged through the primary windings in coil

9. a. Dual ballast resistor

   b. Control unit

   c. Magnetic pickup assembly

   d. Armature or reluctor

10. Discussion should include:

   a. Dual ballast resistor--Maintains constant primary current with variations in engine speed

   b. Magnetic pickup assembly--Sends a small voltage pulse to the control unit to trigger switching transistor to stop current flow in the coil primary windings

   c. Armature or reluctor--Rotates with the distributor shaft, producing a voltage pulse in the magnetic pickup

   d. Control unit--Controls the flow of current in the primary windings of the ignition coil and maintains constant dwell

11. Performance skills evaluated to the satisfaction of the instructor

GENERATOR CHARGING CIRCUITS
UNIT V

UNIT OBJECTIVE

After completion of this unit, the student should be able to state the purpose of the generator charging circuit and explain the operating stages of the charging circuit. The student should also be able to identify the components of a generator and match the components to the correct functions. The student should also be able to test, disassemble, inspect, repair, and reassemble a generator. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with the generator charging circuit to the correct definitions.
2. State the purpose of the generator charging circuit.
3. Name two kinds of charging circuits.
4. Match the names of the components in the DC charging circuit to their functions.
5. Identify the major parts of a generator.
6. Explain the three operating stages of the charging circuit.
7. Explain how current flows in a basic generator.
8. Explain how the field circuit is created in the generator.
9. Explain how the generator converts AC to DC current.
10. Distinguish between an "A" generator field circuit and a "B" generator field circuit.
11. Match the names of the generator regulator components to the correct functions.
12. Match the types of generators to their uses.
13. Match the types of electrical failure to their causes.
14. Explain how reverse polarity in a DC generator can damage the charging circuit.

15. Demonstrate the ability to:

a. Test generator output.

b. Remove and replace a generator.

c. Disassemble, test, and reassemble a generator.

d. Test and adjust a regulator unit.

GENERATOR CHARGING CIRCUITS
UNIT V

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined in the job sheets.

G. Demonstrate lathe turning of commutation.

H. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete job sheets.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Kinds of Charging Circuits
2. TM 2--Parts of the Generator
3. TM 3--Stages of Charging Circuit
4. TM 4--Current Flow in Basic Generator

5. TM 5--AC Converts to DC
6. TM 6--External Generator Regulator and Cut-Out Relays
7. TM 7--External Generator Regulator and Cut-Out Relays (Continued)
8. TM 8--Types of Generators

D. Job sheets

1. Job Sheet #1--Test Generator Output
2. Job Sheet #2--Remove and Replace a Generator
3. Job Sheet #3--Disassemble, Test, and Reassemble a Generator
4. Job Sheet #4--Test and Adjust a Regulator Unit

E. Test

F. Answers to test

II. References:

A. *Fundamentals of Service: Electrical Systems.* Moline, Illinois: Deere and Company, 1972.

B. Stockel, Martin W. *Auto Service and Repair.* Homewood, Illinois: Goodheart-Willcox Company, 1969.

C. Billiet, Walter E., and Leslie F. Goings. *Automotive Electrical Systems.* Third Edition. Chicago, Illinois: American Technical Society, 1970.

GENERATOR CHARGING CIRCUITS
UNIT V

INFORMATION SHEET

I. Terms and definitions

A. Armature--Series of wire conductors in the form of a loop, rotating in a stationary magnetic field

B. Commutator-Bars on end of armature drive shaft and connected to the ends of each wire conductor

C. Pole shoes--Permanent magnets that are fixed to the inside of generator housing, and set opposite each other to create a weak magnetic field

D. Field circuit-One wire conductor wound around both poles many times and attached to the brush

E. Regulator--An assembly which houses the cut-out relay, voltage regulator, and current regulator

F. Arcing--Current attempting to cross between the commutator sections and the brush

G. Polarity--Direction of current flow through the generator

H. Open circuit--Circuit in which a wire is broken or disconnected

I. Short circuit--Wire touching another wire and providing a shorter path for current to flow

J. Grounded circuit--Circuit in which a wire touches ground causing the current to flow to ground instead of through the circuit

II. Purpose of the generator charging circuit--The generator charging circuit recharges the battery and generates current during operation of the engine

III. Kinds of charging circuits (Transparency 1)

(NOTE: Both circuits generate an alternating current, but differ in how they rectify the alternating current to direct current.)

A. Direct current

(NOTE: Direct current charging circuits are associated with generator type systems.)

INFORMATION SHEET

B. Alternating current

(NOTE: Alternating current charging circuits are associated with alternator type systems.)

IV. Components of the DC charging circuit and their functions (Transparency 1)

A. Battery

1. Starts the circuit by supplying spark to start engine

2. Helps out during peak operation when electrical loads are too much for generator or alternator

3. Stabilizes voltage in system

B. Generator

1. Supplies electrical power to accessory circuits

2. Recharges battery

C. Regulator

1. Opens and closes the charging circuit (cut-out relay)

2. Prevents overcharging of battery (voltage regulator)

3. Limits the generator's output to safe rates (current regulator)

D. Ammeter--Measures the rate of current flow

E. Voltmeter--Indicates produced voltage

V. Parts of a generator (Transparency 2)

A. Pulley

B. Fan

C. Drive end frame

D. Generator housing

E. Field coils

F. Commutator

INFORMATION SHEET

G. Thru bolts

H. Brushes

I. Armature

VI. Operating stages of charging circuit (Transparency 3)

A. Starting--Battery supplies all load current

B. Peak operation--Battery helps generator supply current

C. Normal operation--Generator supplies all current and recharges battery

VII. Current flow in basic generator (Transparency 4)

(NOTE: The armature rotates through the magnetic field of the poles generating voltage.)

A. Current flows from armature loop to the commutator ring

(NOTE: The left end of the armature loop is positive while the right end is negative.)

B. Current flows from the commutator ring through brushes to a wire connected to a load

C. Current flows when circuit is complete

VIII. Field circuit wiring--Wire conductors are wound around the magnets (magnetic poles) and connected to the brushes to strengthen the field (Transparency 4)

IX. AC converted to DC current (Transparency 5)

A. The commutator is split in two parts creating a gap as the commutator passes the brushes

(NOTE: This is called the static neutral point where no voltage is created.)

B. Past this point the other half of the commutator contacts the brushes reversing the current flow

C. At the same time the rotating armature reverses its polarity converting AC to DC

X. "A" and "B" generator field circuits

A. "A" generator field circuit--Current flows from the armature circuit through the field to the regulator, then to ground

INFORMATION SHEET

B. "B" generator field circuit-Current flows from the regulator through the field coils to ground

(NOTE: "B" circuits are seldom used in farm and industrial machines.)

XI. Functions of the generator regulator components (Transparencies 6 and 7)

A. Cut-out relay--An automatic switch which closes when generator is running for battery charging and opens when generator stops to prevent battery discharge

B. Voltage regulator--Controls the amount of voltage the regulator produces through a shunt coil and contact points controlling the strength of the magnetic field; prevents overheating

C. Current regulator--Controls the current flow similar to the voltage regulator

(NOTE: Both the voltage regulator and the current regulator are used but while one is working the other is not.)

XII. Types and uses of generators (Transparency 8)

A. Shunt--Used as a standard generator for most normal operations

B. Third brush--Eliminates the use of a current regulator, is relatively easy to change third brush position and control the output, and is used in systems with low speed and low load requirements

C. Interpole--Provides a better commutation point and extends brush life

D. Bucking field--Used where there is a wide variation of load and speed requirements

E. Split field--Used in systems with low speed, but high load requirements

XIII. Types and cause of electrical failure

A. Short circuits--Unwanted connections, usually copper-to-copper, that allow current to bypass all or part of the circuit

B. Open circuits--Breaks in the circuit which cause extremely high resistance

(NOTE: Usually no current will flow through an open circuit.)

INFORMATION SHEET

C. Grounded circuits--Unwanted connections that bypass all or part of the circuit from the insulated side to the grounded side

(NOTE: A grounded circuit is usually a copper-to-iron connection.)

D. High resistance circuits--Usually caused by poor or corroded connections and frayed or damaged wires, creating greater resistance in the circuit

XIV. Reverse polarity

A. Generator polarity is opposite that of the battery

B. Battery is in series with the generator

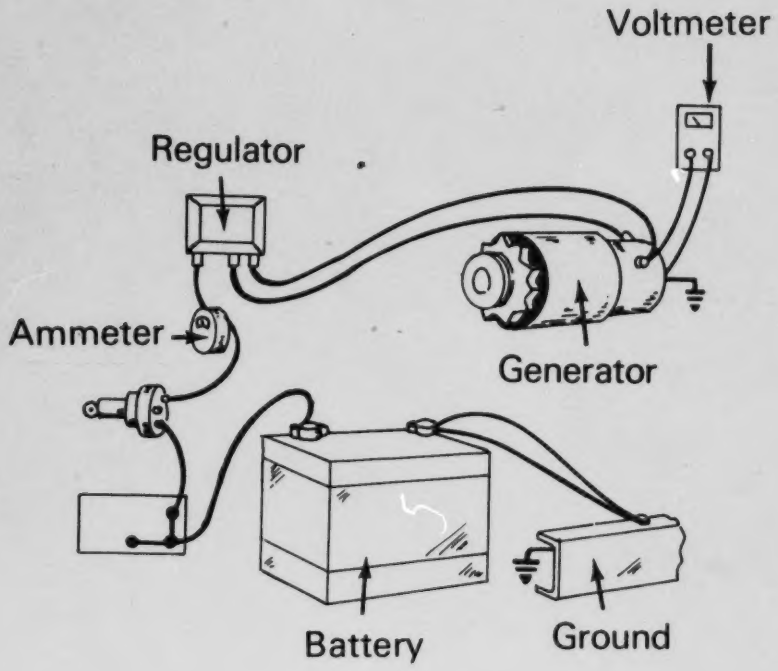
C. Generator builds up voltage and closes the cut-out relay points

D. High voltage can create enough current and heat to weld the points together

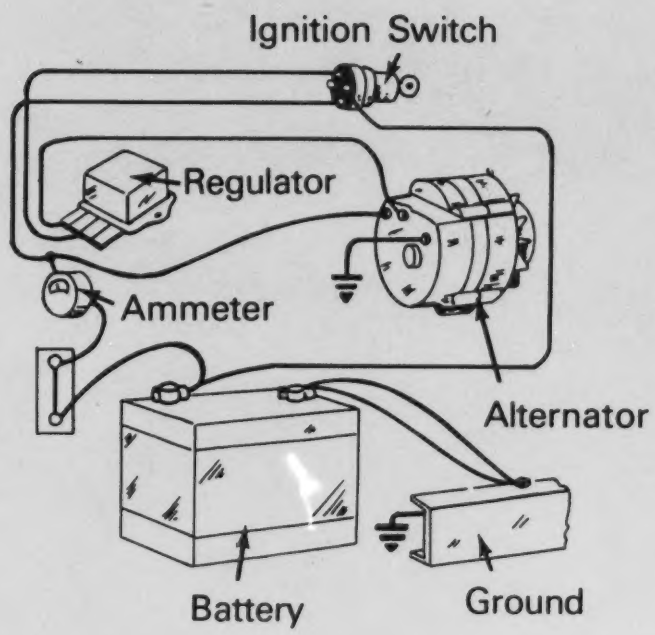
(CAUTION: After any service polarize the DC generator.)

(NOTE: Pole shoe polarity is determined by the magnetism of the field coils the last time current passed through the coils; a slight current through the field coils when servicing can accidentally change pole polarity.)

Kinds Of Charging Circuits

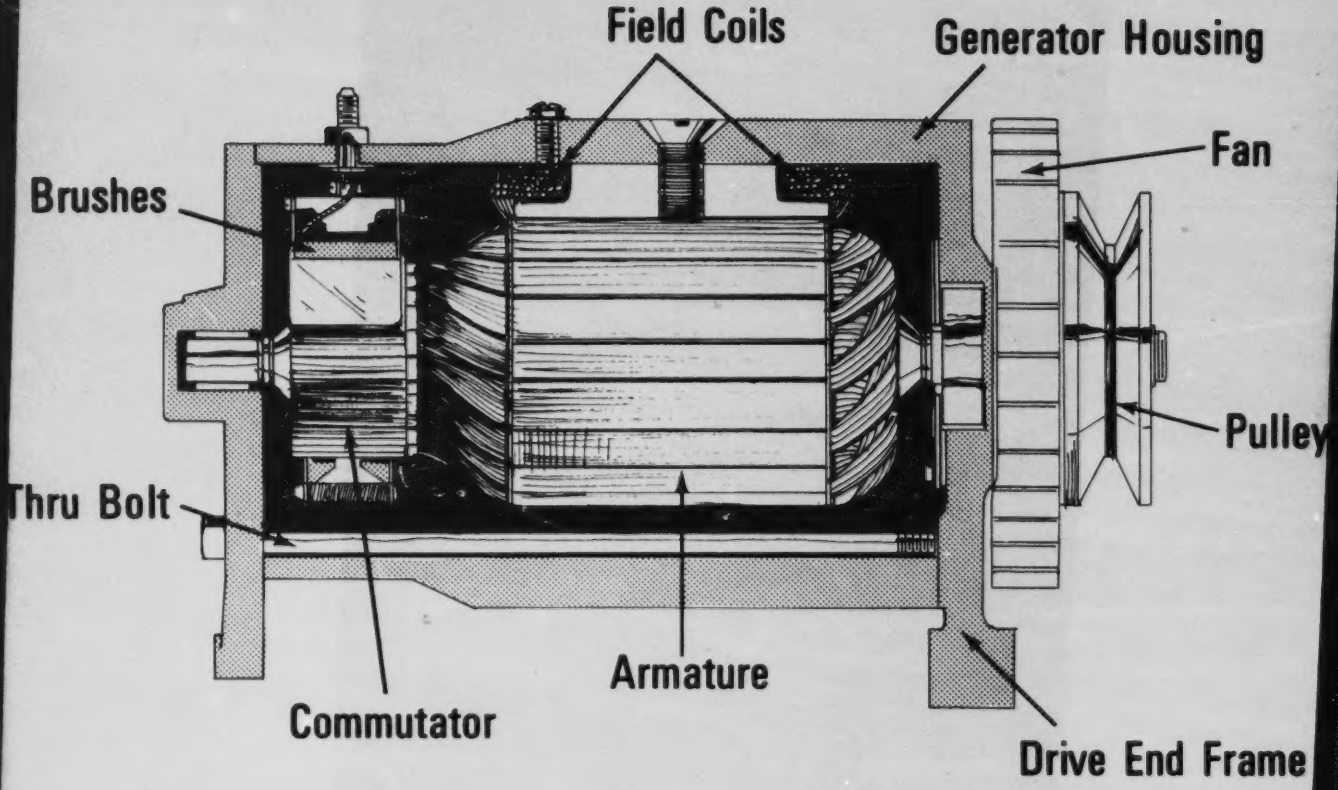


GENERATOR



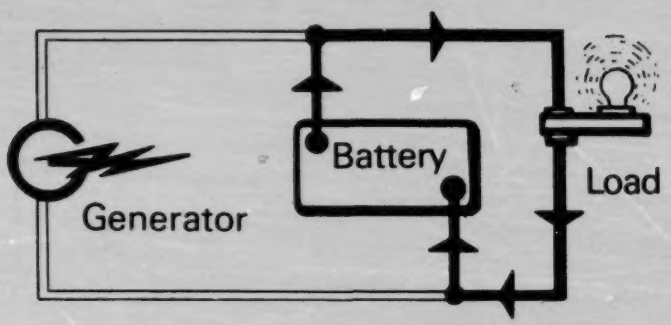
ALTERNATOR

Parts of the Generator

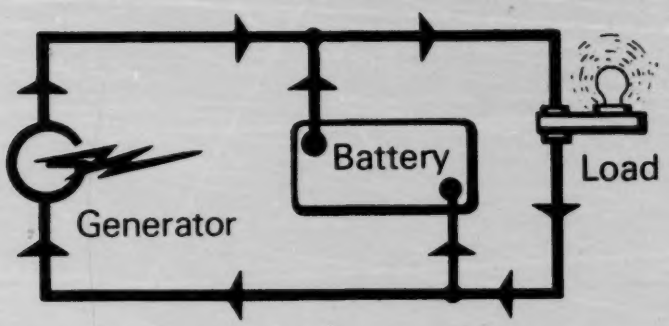


1011

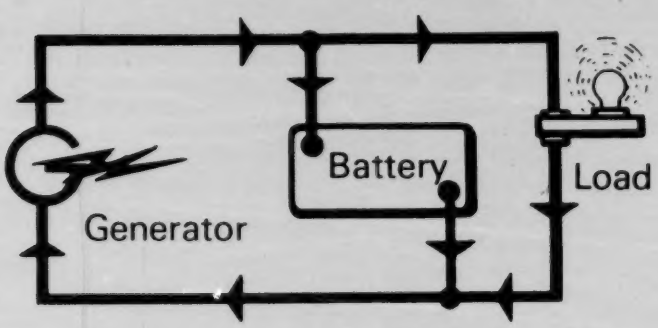
Stages Of Charging Circuit



BATTERY SUPPLYING LOAD CURRENT

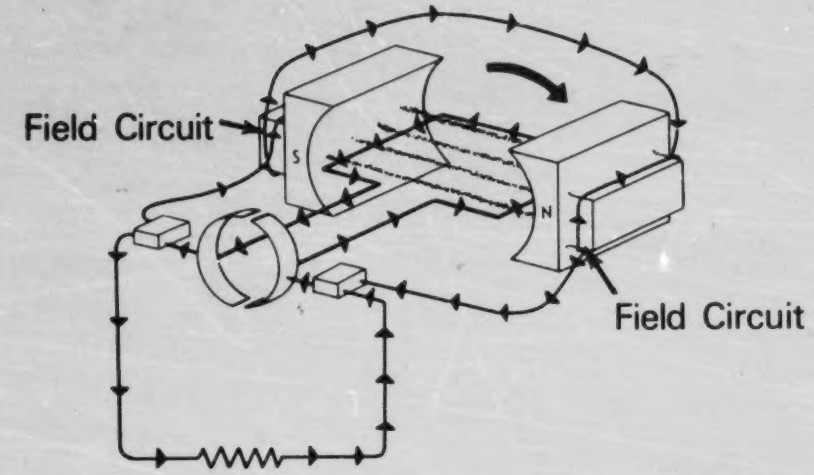


GENERATOR AND BATTERY
SUPPLYING LOAD CURRENT

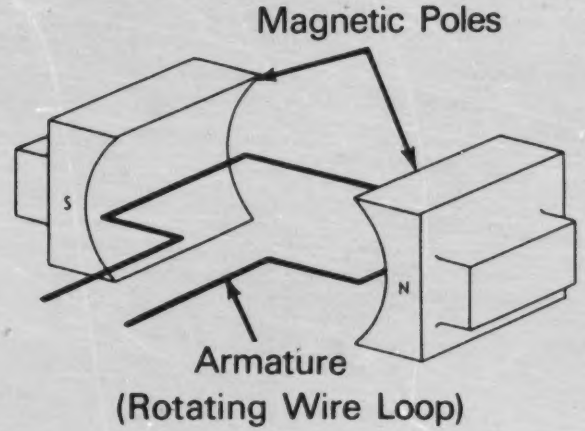


GENERATOR SUPPLYING LOAD
CURRENT AND CHARGING BATTERY

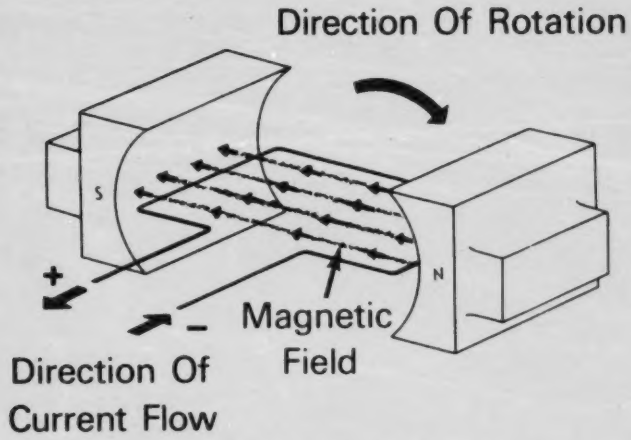
Current Flow In Basic Generator



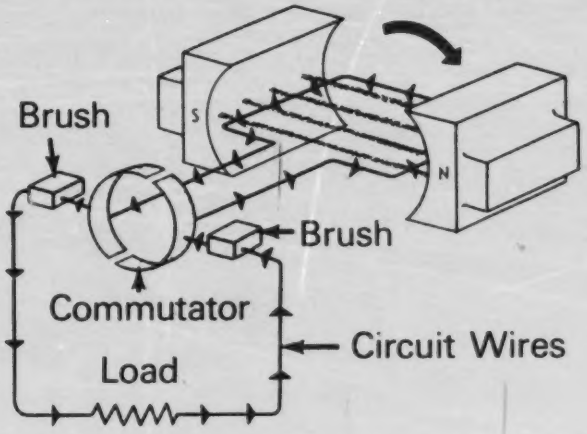
COMPLETE PARTS OF BASIC GENERATORS



THE BASIC PARTS OF A GENERATOR



BASIC GENERATED VOLTAGE



BASIC CURRENT FLOW IN GENERATOR

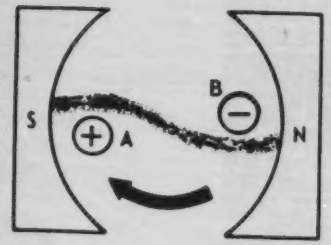
TM 4

D - 215-F

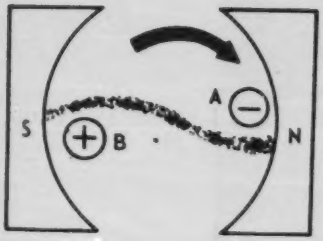
1013

1014

AC Converts To DC



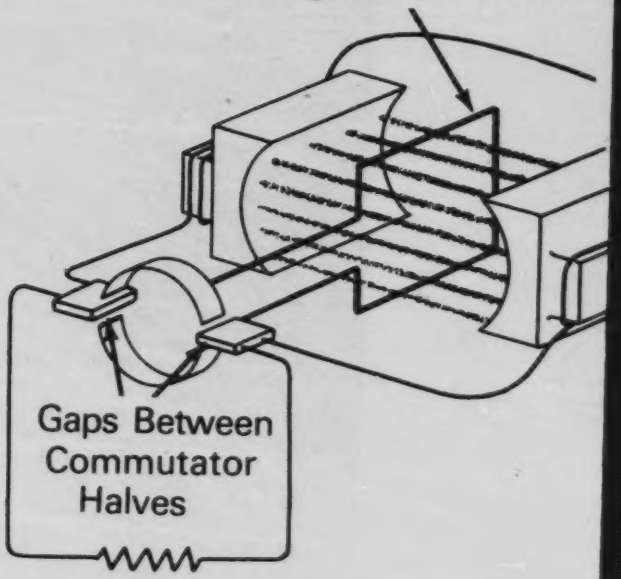
First Half
Of Revolution



Second Half
Of Revolution

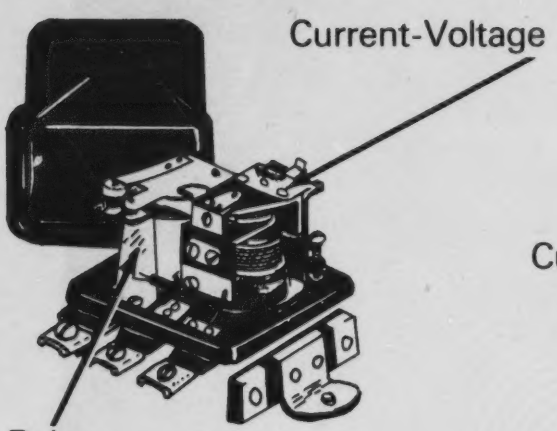
HOW THE POLARITY OF THE ARMATURE
CHANGES DURING EACH REVOLUTION

At Static "Neutral Point"
No Voltage Is Generated

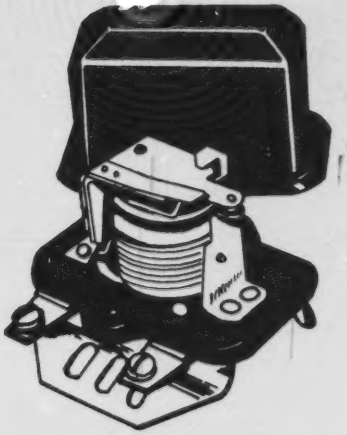


HOW GENERATOR CONVERTS
A.C. TO D.C. CURRENT

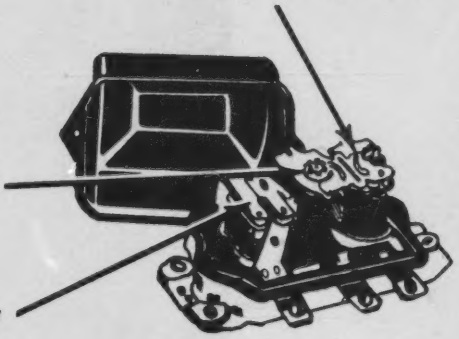
External Generator Regulator And Cut-Out Relay



CUTOUT RELAY
CURRENT-VOLTAGE REGULATOR



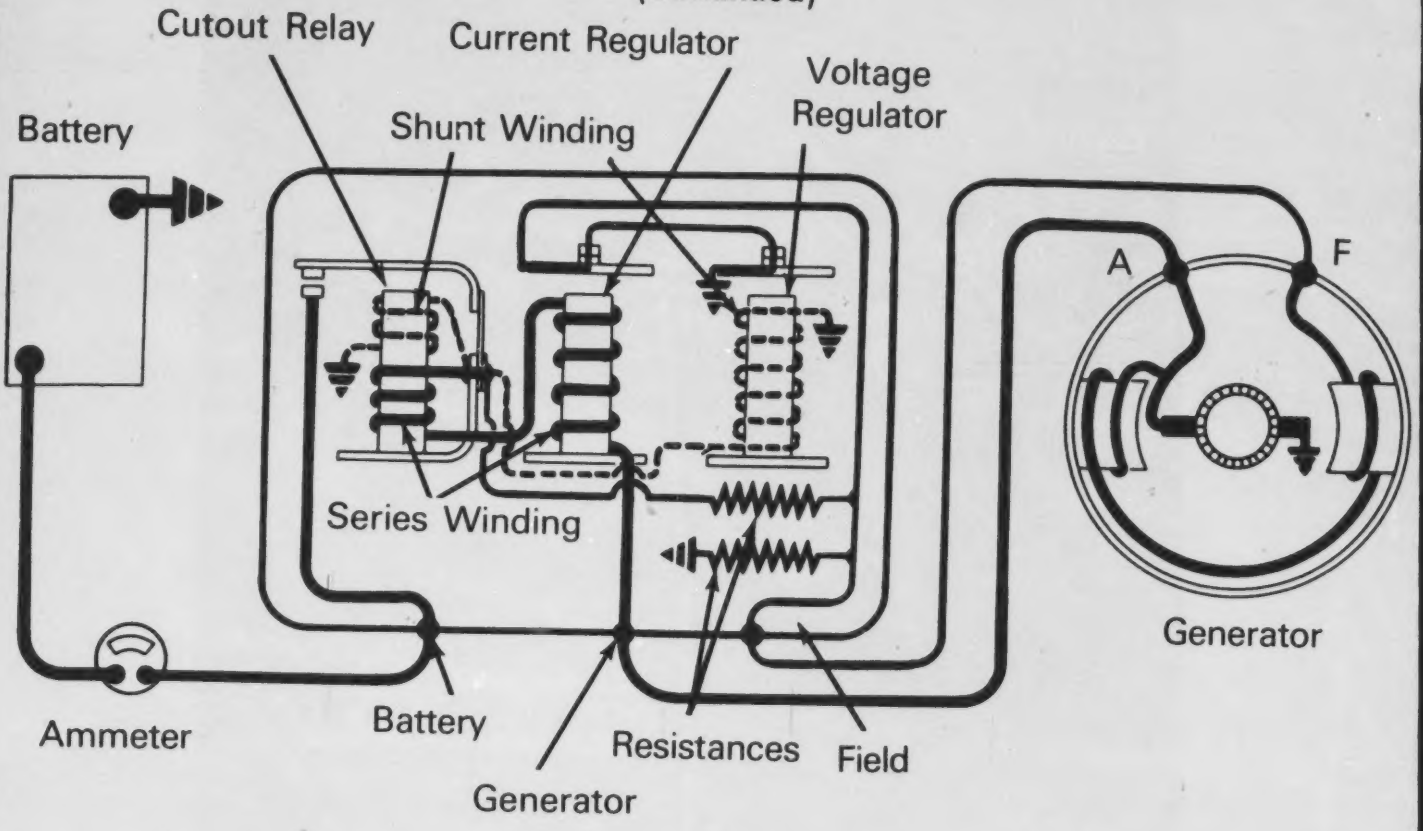
CUTOUT RELAY
1016



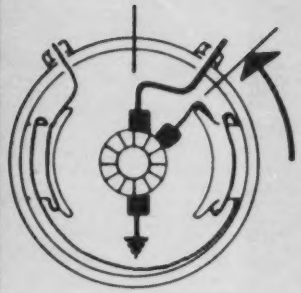
CUTOUT RELAY,
CURRENT REGULATOR
AND
VOLTAGE REGULATOR

External Generator Regulator And Cut-Out Relay

(Continued)



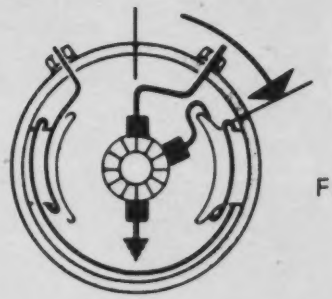
Types Of Generators



Higher Output

FIELD

Increased Voltage
Increased Current
Greater Magnetic Strength

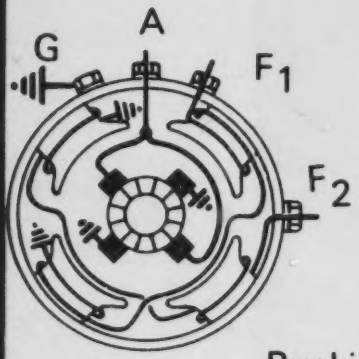


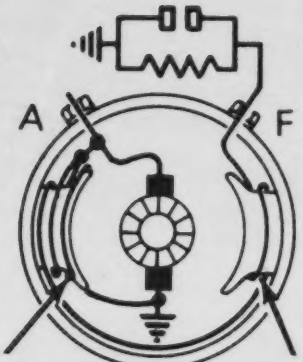
Lower Output

FIELD

Reduced Voltage
Decreased Current
Less Magnetic Strength

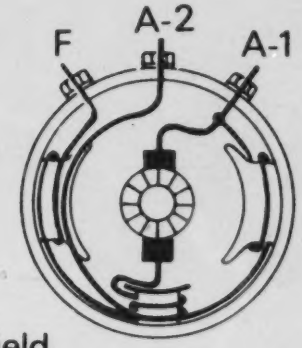
THIRD BRUSH

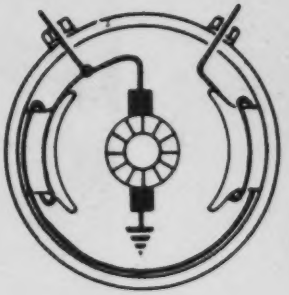




Bucking Field

Normal Field





SPLIT FIELD

BUCKING FIELD

INTERPOLE

SHUNT

GENERATOR CHARGING CIRCUITS
UNIT V

JOB SHEET #1--TEST GENERATOR OUTPUT

I. Tools and materials

A. Basic hand tool set

B. Switch

C. Ammeter

D. Voltmeter

E. Carbon pile

F. Jumper leads

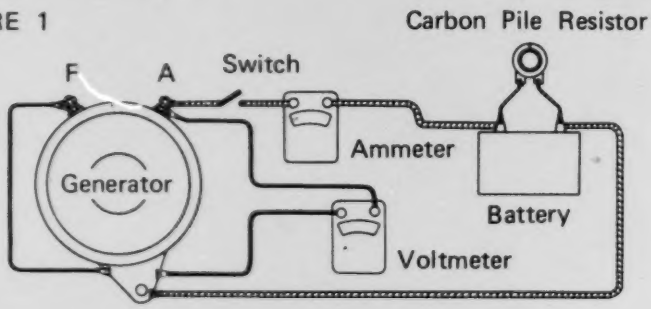
G. Generator specifications manual

H. Safety glasses

II. Procedure

A. Connect an ammeter and switch in series with a battery to the generator output terminal (Figure 1)

FIGURE 1



TESTING THE GENERATOR OUTPUT

B. Connect a voltmeter from the generator output terminal to ground (Figure 1)

C. Connect a carbon pile across the battery (Figure 1)

D. Connect a jumper lead to the generator field terminal (Figure 1)

E. Operate the generator to obtain battery voltage and close the switch

F. Speed up the generator to its rated value, and adjust the carbon pile to obtain the specified voltage

JOB SHEET #1

G. Compare the current output with the generator specifications

H. If the generator output is below par, disassemble it for further testing

(NOTE: The output test shown in Figure 1 is for the common "A" circuit generator. For "B" circuit models, a different test hookup is used.)

GENERATOR CHARGING CIRCUITS
UNIT V

JOB SHEET #2--REMOVE AND REPLACE A GENERATOR

I. Tools and materials

A. Basic hand tool set

B. Belt tension gauge

C. Battery cable puller

D. Shop towels

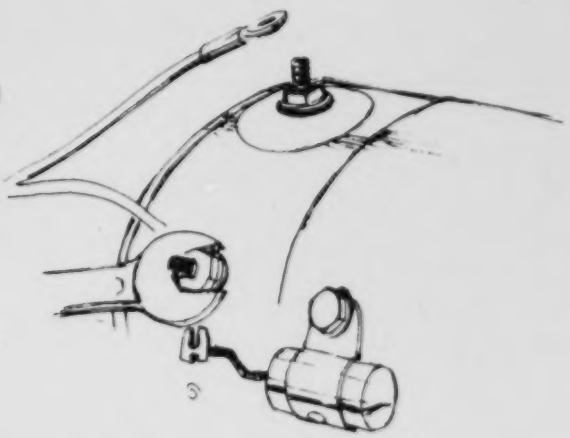
E. Safety glasses

II. Procedure

(NOTE: Always disconnect battery cable before working on charging circuits.)

A. Remove the leads from the generator terminals (Figure 1)

FIGURE 1

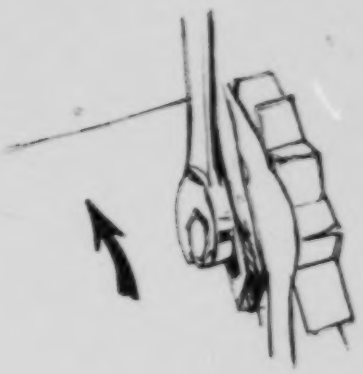


B. Remove the generator belt adjusting bolt from the generator

JOB SHEET #2

C. Move the generator [illegible]ward the engine (Figure 2)

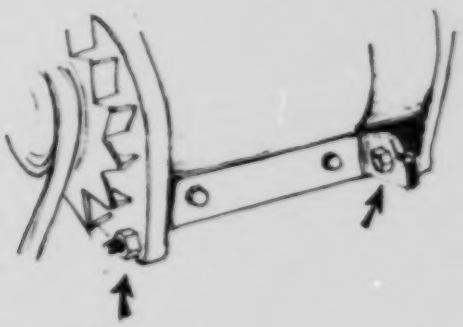
FIGURE 2



D. Remove the generator belt from the generator pulley

E. Remove the bolts holding the generator to the engine mounting bracket (Figure 3)

FIGURE 3



F. Lift the generator out of the bracket

G. Service the generator as required

H. Replace by positioning the generator in the engine mounting bracket

I. Start generator retaining bolts and tighten securely

J. Position generator belt on pulley and move generator away from engine to tighten belt

K. Install generator adjusting bolt

JOB SHEET #2

L. Pry the generator away from engine to adjust generator belt and tighten adjustment bolt

M. Check generator belt tension with a belt tension gauge and adjust to manufacturer's specifications (Figure 4)

FIGURE 4

CHECK BELT FOR TIGHTNESS

N. Install wire leads that were removed from generator

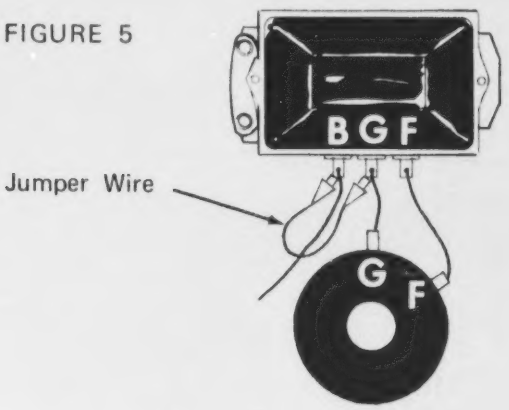
(NOTE: On installations using the condenser on generator, the condenser lead is attached to the "A" terminal, never the "F" terminal.)

JOB SHEET #2

O. Before starting engine, polarize the generator

1. Polarize negative grounded circuit generators by holding one end of a jumper wire against the regulator BAT terminal, and scratch the other end of the jumper wire on the regulator GEN terminals (Figure 5)

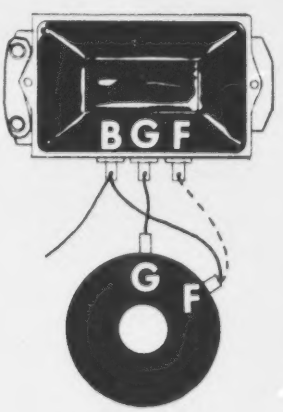
FIGURE 5



"A" CIRCUIT

2. Polarize positive grounded circuit generators by removing the lead from the FIELD terminal of the regulator and strike (or momentarily touch) the F-lead to the BAT terminal of the regulator (Figure 6)

FIGURE 6



"B" CIRCUIT

GENERATOR CHARGING CIRCUITS
UNIT V

JOB SHEET #3--DISASSEMBLE, TEST, AND REASSEMBLE A GENERATOR

I. Tools and materials

A. Basic hand tool set

B. Growler

C. Test lamp or volt-ohmmeter

D. Generator pulley puller

E. Ball bearing grease

F. Hacksaw blade

G. Spring tension gauge

H. Shop towels

I. Eye protection

II. Procedure

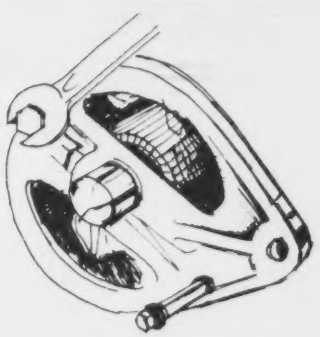
A. Disassemble generator

(NOTE: Scribe generator case before separating.)

1. Remove generator thru bolts (Figure 1)

FIGURE 1

REMOVE THRU BOLTS

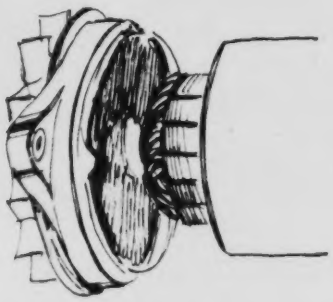


JOB SHEET #3

2. Lightly tap the generator commutator end frame and remove from housing

3. Remove the drive end frame and armature assembly from the generator housing (Figure 2)

FIGURE 2



REMOVE DRIVE END FRAME AND ARMATURE ASSEMBLY

4. Remove the generator brushes (Figure 3)

FIGURE 3

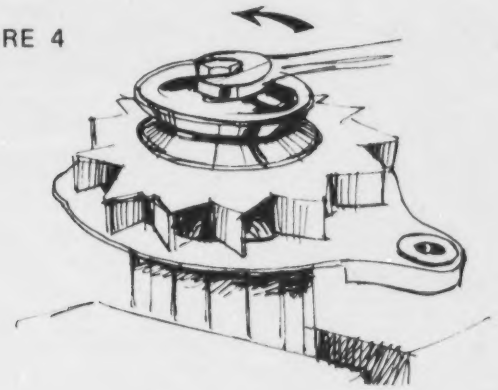
REMOVE BRUSHES

JOB SHEET #3

5. Place the armature and drive end frame assembly in a vise (Figure 4)

(NOTE: Use brass jaws on vise.)

FIGURE 4

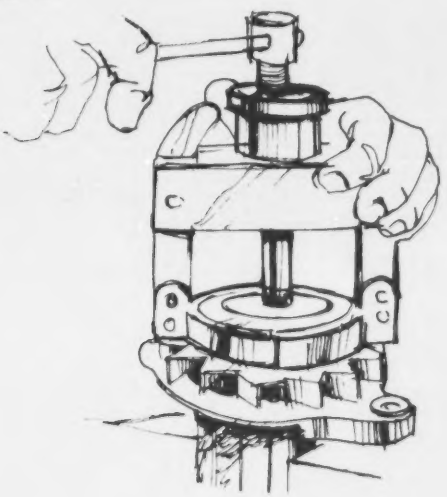


REMOVE PULLEY NUT

6. Remove the pulley nut

7. Remove the pulley from the armature using a pulley puller as required (Figure 5)

FIGURE 5



REMOVE PULLEY

JOB SHEET #3

8. Slide the drive end frame and spacer columns off armature shaft

9. Remove armature from vise

10. Remove bearing retainer and gasket from drive end frame

11. Remove drive end bearing from drive end frame

B. Service and test

1. Clean all generator components

(NOTE: Do not wash the fields or armature with a degreasing solvent.)

2. Inspect generator drive end frame bearings for roughness or scored races

3. Inspect generator brush holders to see if they are bent or deformed; check generator brush springs for proper spring tension

4. Check fit of armature shaft in bushing in commutator end frame

(NOTE: If bushing is excessively worn, the end frame should be replaced.)

5. Inspect armature commutator for roughness or out-of-round

(NOTE: If armature commutator is rough or out-of-round, it should be turned or serviced on an armature turning lathe.)

6. Test armature for shorts (Figure 6)

a. Place the armature on a growler and turn on

b. Rotate the armature while holding a hacksaw blade over the armature core

(NOTE: If the blade vibrates, the armature is shorted and will require replacement.)

JOB SHEET #3

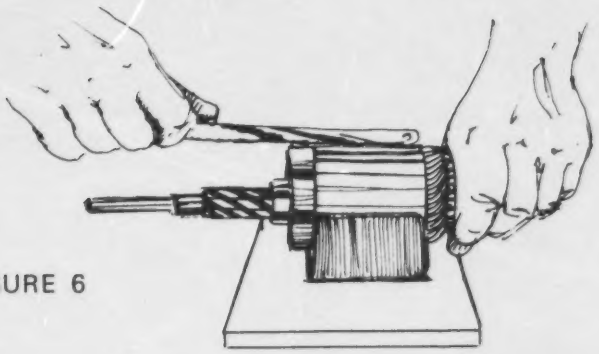


FIGURE 6

ARMATURE TEST FOR SHORTS

7. Test armature for ground (Figure 7)

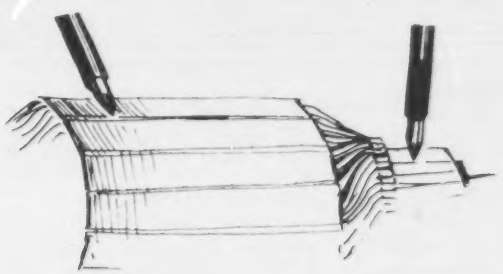
   a. Place one lead of a test lamp on the armature core or shaft

   b. Touch second lead to the commutator segments on the commutator

   c. Rotate the lead around the commutator, being certain to touch all segments

(NOTE: If the lamp lights, the armature is grounded and will require replacement.)

FIGURE 7



ARMATURE TEST FOR GROUND

8. Test armature for open

   a. Place one lead on a commutator segment

JOB SHEET #3

b. Place the other lead on the segment common with it

(NOTE: On a two brush generator they will be 180° apart, on a three brush they'll be 120° apart. The light should burn between these common segments.

c. Proceed around commutator until all segments have been checked

9. Test field coil for open circuit (Figure 8)

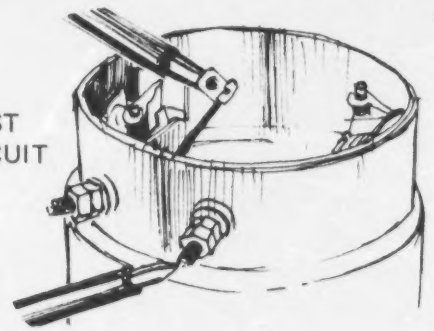
a. Place one lead of a test lamp on field terminal

b. Place the other lead on the end of the field coil lead through the armature terminal

(NOTE: If lamp does not light, the fields are open and must be replaced.)

FIGURE 8

FIELD COIL TEST
FOR OPEN CIRCUIT



10. Test field coil for ground (A circuit only) (Figure 9)

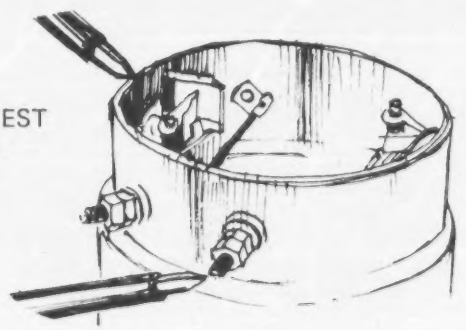
a. Place one lead of a test lamp on generator housing

b. Place the other lead on field terminal

(NOTE: If lamp lights, the field coils are grounded and must be repaired or replaced.)

FIGURE 9

FIELD COIL TEST
FOR GROUND



JOB SHEET #3

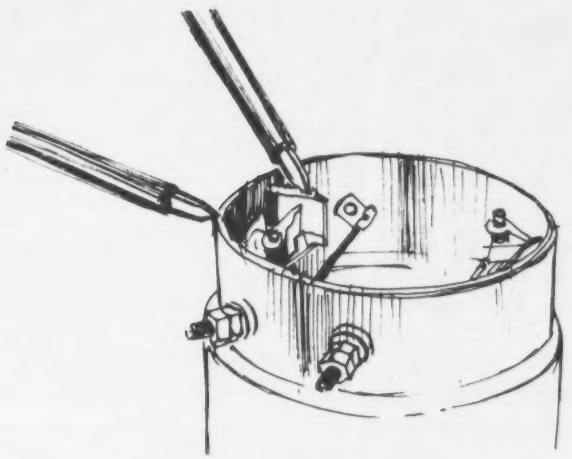
11. Check insulated brush holder for ground (Figure 10)

    a. Place one lead of a test lamp on brush holder

    b. Place the other lead on the generator housing

    (NOTE: If lamp lights, insulated brush is grounded and must be repaired.)

FIGURE 10



INSULATED BRUSH HOLDER TEST FOR GROUND

12. Inspect all parts for wear or damage

13. Replace all damaged or worn parts

C. Reassemble generator

1. Pack the generator ball bearings with high melting point ball bearing grease

2. Install the ball bearing in the drive end frame

   (NOTE: Make sure gasket is in place and retainer screws tightened securely.)

3. Install the drive end frame and bearing assembly onto armature shaft

   (NOTE: Make sure ball bearing spacers are in place if used.)

JOB SHEET #3

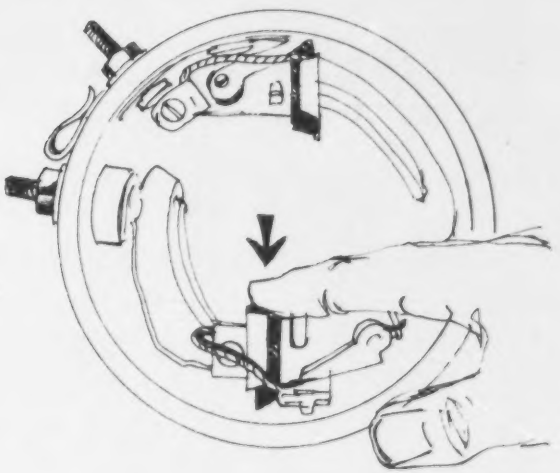
4. Install ball bearing spacers, fan, pulley, and retaining nut

5. Tighten retaining nut securely

6. Install new brushes in brush holders and push brushes back against spring tension (Figure 11)

   (NOTE: If brushes are over 1/2 of original length they can be reused.)

FIGURE 11



PUSH BRUSHES BACK AGAINST SPRING

7. Install armature and drive end frame assembly into generator housing

8. Release brushes so they will contact commutator

9. Assemble commutator end frame over end of armature shaft

10. Rotate both end frames until dowels engage, then start thru bolts

11. Tighten thru bolts securely

12. Check generator operation before replacing on vehicle

GENERATOR CHARGING CIRCUITS
UNIT V

JOB SHEET #4--TEST AND ADJUST A REGULATOR UNIT

I. Tools and materials

A. Basic hand tool set

B. Air gap gauge

C. Technical manual for regulator

D. 1/4 ohm fixed resistor

E. Voltmeter

F. Variable resistor

G. Safety glasses

II. Procedure

A. Test and adjust voltage regulator

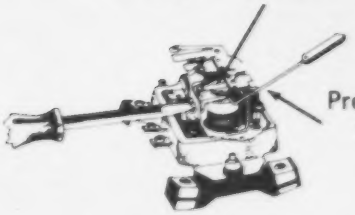
1. Measure air gap

a) Push down on the armature until points are just touching

b) Measure the gap between the armature and the core with proper size gauge as specified by the technical manual

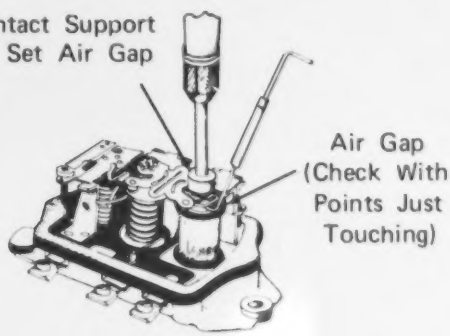
c) Adjust gap as specified by technical manual (Figure 1)

(NOTE: On some regulators, a screw post at the top of the unit is adjusted to lengthen or shorten the distance) Figure 1)



STANDARD VOLTAGE REGULATOR

FIGURE 1



POST-TYPE VOLTAGE REGULATOR

JOB SHEET #4

2. Test voltage setting

a. Test using fixed resistance method

1) Insert a 1/4-ohm fixed resistor into the charging circuit at the battery terminal. (Figure 2)

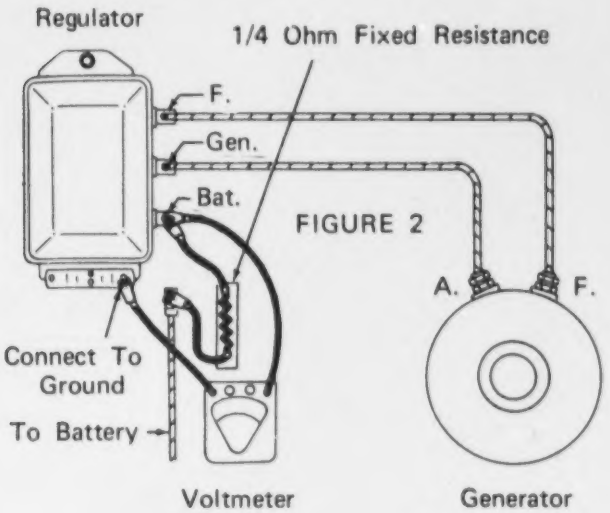


FIGURE 2

FIXED RESISTANCE METHOD

2) Connect a voltmeter from the battery terminal to ground

3) Operate the circuit for 15 minutes at specified speed to warm it up

4) Cycle the generator by one of two methods:

a) Slow it down until voltage drops to about 1/4 of rated value

b) Cycle the generator by inserting a variable resistance into the field circuit

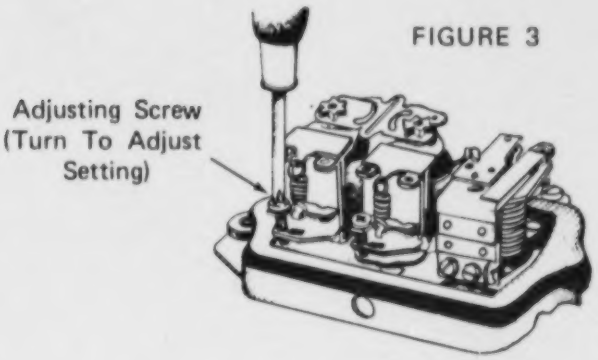
5) Slowly increase resistance until voltage drops to about 1/4 of rated value

6) Decrease the resistance and note the voltage reading

JOB SHEET #4

7) Adjust the voltage setting by turning the adjusting screw (Figure 3)

FIGURE 3



VOLTAGE SETTING ADJUSTMENT

(NOTE: If the adjusting screw is turned to its limits, it may be necessary to bend the spring support. However, do this very carefully.)

8) Make final adjustment by increasing the spring tension

(NOTE: If the setting is too high, adjust the unit below the specified value and then bring it back to this value by increasing the spring tension.)

9) After each adjustment and before taking a reading, replace the cover and cycle the generator

b. Test using variable resistance method

1) Connect a variable resistor and an ammeter into the charging circuit at the battery terminal (Figure 4)

JOB SHEET #4

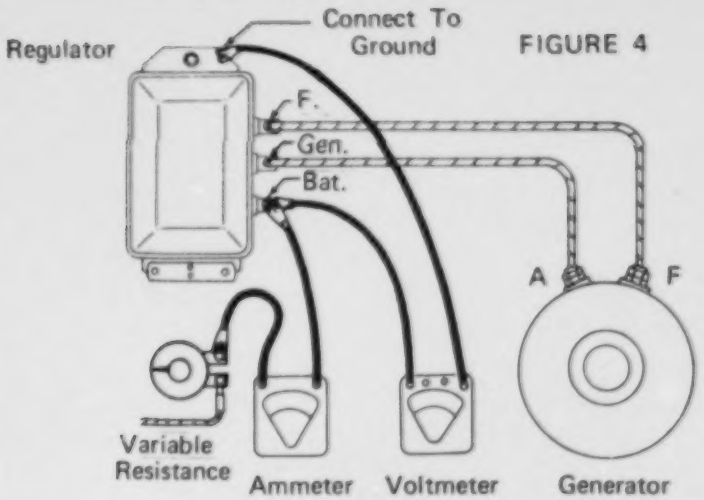


FIGURE 4

VARIABLE RESISTANCE METHOD

Checking The Voltage Setting Of Voltage Regulator

2) Connect a voltmeter from the battery terminal to ground

3) Start generator and adjust resistor to get a current flow of not more than 10 amperes

4) Operate the generator at specified speed to warm it up

5) Cycle the generator as in a4) above

6) Adjust the voltage as in a5) above

B. Test and adjust cut-out relay

1. Check air gap

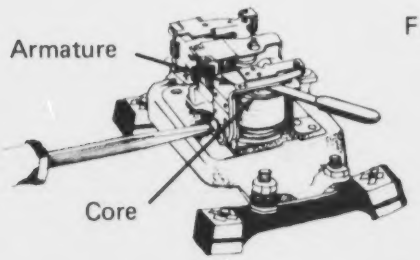
a. Disconnect battery from regulator

b. Push the cut-out armature down until the points are just touching

JOB SHEET #4

c. Measure the air gap between the armature and the center of the core using a feeler gauge (Figure 5)

FIGURE 5



AIR GAP ADJUSTMENT OF CUTOUT RELAY

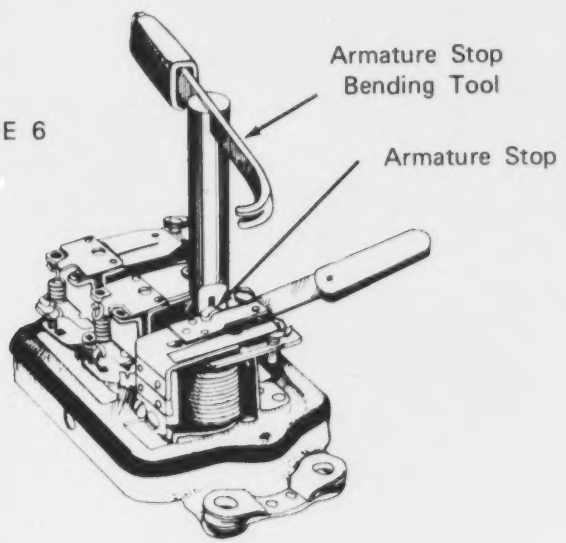
d. Adjust the air gap

e. Raise or lower the armature as needed and make sure the points are aligned

f. Tighten the screws after adjustment

2. Check point opening and adjust by bending the armature stop with a tool (Figure 6)

FIGURE 6



POINT OPENING CHECK

JOB SHEET #4

3. Check closing voltage

   a. Connect voltmeter between the generator terminal and ground (Figure 7)

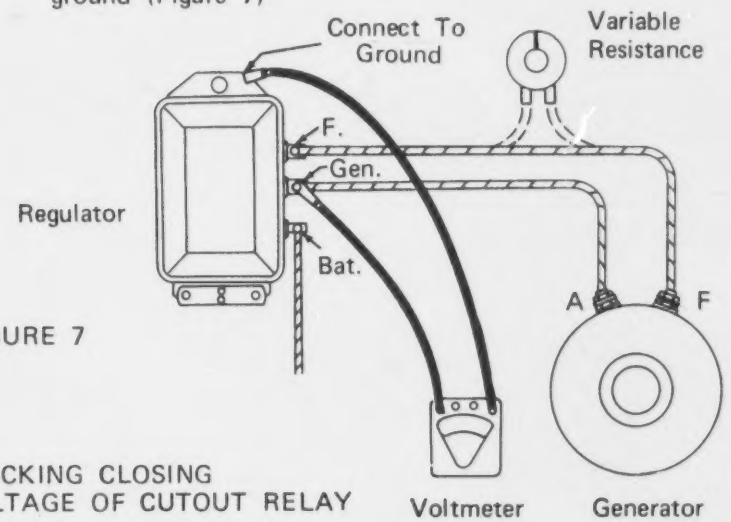


FIGURE 7

CHECKING CLOSING VOLTAGE OF CUTOUT RELAY

   b. Slowly increase the generator speed and note the relay closing voltage

   c. Decrease the speed and make sure the points open before specified current flow is exceeded (with the battery connected)

JOB SHEET #4

d. Adjust the closing voltage (Figure 8)

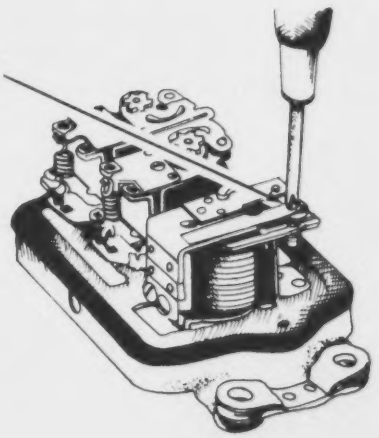


FIGURE 8

ADJUSTING CLOSING VOLTAGE OF CUTOUT RELAY

e. Turn the screw clockwise to increase setting

C. Test current regulator

1. Test and adjust air gap as in B.1., voltage regulator above

2. Check current setting

(NOTE: Most current regulators have a temperature compensation. For these units, make the following test by the "load method.")

a. Connect an ammeter into the charging circuit (Figure 9)

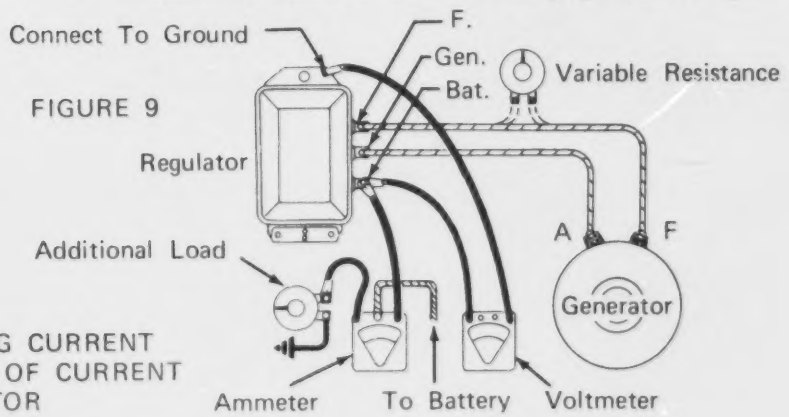


FIGURE 9

CHECKING CURRENT SETTING OF CURRENT REGULATOR

JOB SHEET #4

b. Turn on all accessories and connect an additional load across the battery (such as a bank of lights) to drop the system voltage about 1 volt below the voltage regulator setting

c. Operate the generator at specified speed to warm it up

d. Cycle the generator and note the current setting

e. Adjust the setting in the same way as for voltage setting (Figure 3)

(NOTE: Before slowing down the generator, be sure to remove the extra load. This will prevent overloading of the wiring.)

D. Clean contact points

1. Remove upper contact support (Figure 10)

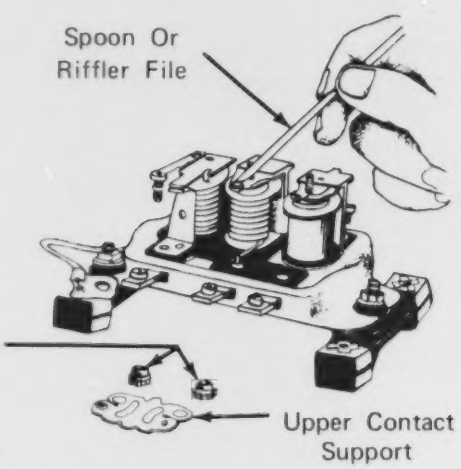


FIGURE 10

CLEANING THE REGULATOR CONTACT POINTS

2. Clean the points with a riffler file or crocus cloth and then wash

(NOTE: Never use emery cloth or sandpaper to clean the contact points. However, No. 400 grit silicone carbide paper or cloth may be used.)

GENERATOR CHARGING CIRCUITS
UNIT V

NAME _____

TEST

1. Match the terms on the right to the correct definitions.

_____a. Series of wire conductors in the form of a loop, rotating in a stationary magnetic field

_____b. Bars on end of armature drive shaft and connected to the ends of each wire conductor

_____c. Permanent magnets that are fixed to the inside of generator housing, and set opposite each other to create a weak magnetic field

_____d. One wire conductor wound around both poles many times and attached to the brush

_____e. An assembly which houses the cut-out relay, voltage regulator, and current regulator

_____f. Current attempting to cross between the commutator sections and the brush

_____g. Direction of current flow through the generator

_____h. Circuit in which a wire is broken or disconnected

_____i. Wire touching another wire and providing a shorter path for current to flow

_____j. Circuit in which a wire touches ground causing the current to flow to ground instead of through the circuit

1. Arcing
2. Pole shoes
3. Field circuit
4. Regulator
5. Armature
6. Commutator
7. Polarity
8. Open circuit
9. Grounded circuit
10. Short circuit

2. State the purpose of the generator charging circuit.

3. Name two kinds of charging circuits.

a.

b.

4. Match the names of the components in the DC charging circuit on the right to their correct functions.

_____a. Starts the circuit by supplying spark to start engine

_____b. Measures the rate of current flow

_____c. Supplies electrical power to accessory circuits

_____d. Prevents overcharging of battery (voltage regulator)

_____e. Opens and closes the charging circuit (cut-out relay)

_____f. Indicates produced voltage

_____g. Limits the generator's output to safe rates (current regulator)

_____h. Helps out during peak operation when electrical loads are too much for generator or alternator

_____i. Recharges battery

1. Ammeter
2. Generator
3. Regulator
4. Battery
5. Voltmeter

5. Identify the major parts of a generator.

a. _____

b. _____

c. _____

d. _____

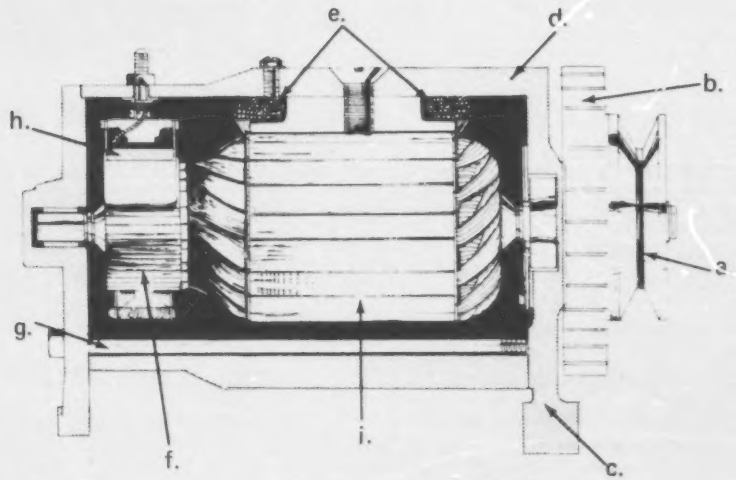
e. _____

f. _____

g. _____

h. _____

i. _____



6. Explain three operating stages of the charging circuit.

   a. Starting--

   b. Peak operation--

   c. Normal operation--

7. Explain how current flows in a basic generator.

   a.

   b.

   c.

8. Explain how the field circuit is created in the generator.

9. Explain how the generator converts AC to DC current.

   a.

   b.

   c.

10. Distinguish between an "A" generator field circuit and a "B" generator circuit by placing an "X" next to the description of an "A" generator field circuit.

_____a. Current flows from the regulator through the field coils to ground

_____b. Current flows from the armature circuit through the field to the regulator, then to ground

11. Match the names of the generator regulator components on the right to their correct functions.

_____a. An automatic switch which closes when generator is running for battery charging and opens when generator stops to prevent battery discharge

_____b. Controls the amount of voltage the regulator produces through a shunt coil and contact points controlling the strength of the magnetic field; prevents overheating

_____c. Controls the current flow similar to the voltage regulator

1. Voltage regulator
2. Current regulator
3. Cut-out relay

12. Match the types of generators on the right to their uses.

_____a. Used as a standard generator for most normal operations

_____b. Eliminates the use of a current regulator, is relatively easy to change third brush position and control the output, and is used in systems with low speed and low load requirements

_____c. Provides a better commutation point and extends brush life

_____d. Used where there is a wide variation of load and speed requirements

_____e. Used in systems with low speed, but high load requirements

1. Split field
2. Interpole
3. Third brush
4. Shunt
5. Bucking field

13. Match the types of electrical failure on the right to their causes.

_____a. Unwanted connections, usually copper-to-copper, that allow current to bypass all or part of the circuit

_____b.	Breaks in the circuit which cause extremely high resistance	1.	Open circuits
_____c.	Unwanted connections that bypass all or part of the circuit from the insulated side to the grounded side	2.	Grounded circuits
_____d.	Usually caused by poor or corroded connections and frayed or damaged wires, creating greater resistance in the circuit	3.	High resistance circuits
		4.	Short circuits

14. Explain how reverse polarity in a DC generator can damage the charging circuit.

15. Demonstrate the ability to:

    a. Test generator output.

    b. Remove and replace a generator.

    c. Disassemble, test, and reassemble a generator.

    d. Test and adjust a regulator unit.

    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

GENERATOR CHARGING CIRCUITS
UNIT V

ANSWERS TO TEST

1. a. 5
   b. 6
   c. 2
   d. 3
   e. 4
   f. 1
   g. 7
   h. 8
   i. 10
   j. 9

2. The generator charging circuit recharges the battery and generates current during operation of the engine

3. a. Direct current
   b. Alternating current

4. a. 4
   b. 1
   c. 2
   d. 3
   e. 3
   f. 5
   g. 3
   h. 4
   i. 2

5. a. Pulley
   b. Fan
   c. Drive end frame
   d. Generator housing
   e. Field coils
   f. Commutator
   g. Thru bolts
   h. Brushes
   i. Armature

6. a. Starting--Battery supplies all load current

   b. Peak operation--Battery helps generator supply current

   c. Normal operation--Generator supplies all current and recharges battery

7. a. Current flows from armature loop to the commutator ring

   b. Current flows from the commutator ring through brushes to a wire connected to a load

   c. Current flows when circuit is complete

8. Wire conductors are wound around the magnets (magnetic poles) and connected to the brushes to strengthen the field

9. a. The commutator is split in two parts creating a gap as the commutator passes the brushes

   b. Past this point the other half of the commutator contacts the brushes reversing the current flow

   c. At the same time the rotating armature reverses its polarity converting AC to DC

10. b

11. a. 3

    b. 1

    c. 2

12. a. 4

    b. 3

    c. 2

    d. 5

    e. 1

13. a. 4

    b. 1

    c. 2

    d. 3

14. a. Generator polarity is opposite that of the battery

    b. Battery is in series with the generator

    c. Generator builds up voltage and closes the cut-out relay points

    d. High voltage can create enough current and heat to weld the points together

15. Performance skills evaluated to the satisfaction of the instructor

ALTERNATOR CHARGING CIRCUITS
UNIT VI

UNIT OBJECTIVE

After completion of this unit, the student should be able to state the purpose of the alternator charging circuit and explain the differences between an alternator and generator. The student should be able to identify the components of an alternator, match the component to the correct function, and test, disassemble, inspect, repair, and reassemble an alternator. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with the alternator charging circuit to the correct definitions.
2. State the purpose of the alternator charging circuit.
3. Match the names of the alternator charging circuit components to the correct functions.
4. Identify the major parts of an alternator.
5. Explain the differences between an alternator and a generator.
6. List two advantages of an alternator as opposed to a generator.
7. Explain why the alternator produces more current at low speed than a generator.
8. Discuss the construction of the stator windings.
9. Discuss how the alternator is controlled by the regulator.
10. Match the component parts of a transistorized regulator to the correct functions.
11. Discuss the operation of the transistorized regulator.
12. List safety rules for working with alternator charging circuits.
13. Demonstrate the ability to:
    a. Test the alternator charging circuit and regulator.
    b. Remove and replace an alternator.
    c. Disassemble, test, and reassemble an alternator.
    d. Test and repair a transistorized regulator.

ALTERNATOR CHARGING CIRCUITS
UNIT VI

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined in the job sheets.

G. Demonstrate diode removal procedure.

H. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete job sheets.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Alternator Charging Circuit Components
2. TM 2--Alternator Circuit Schematic
3. TM 3--Parts of the Alternator
4. TM 4--Differences in Alternator and Generator
5. TM 5--Stator Winding Construction

D. Job sheets

1. Job Sheet #1--Test the Alternator Charging Circuit and Regulator
2. Job Sheet #2--Remove and Replace an Alternator
3. Job Sheet #3--Disassemble, Test, and Reassemble an Alternator
4. Job Sheet #4--Test and Repair a Transistorized Regulator

E. Test

F. Answers to test

II. References:

A. *Fundamentals of Service: Electrical Systems.* Moline, Illinois: Deere and Company, 1972.

B. Stockel, Martin W. *Auto Service and Repair.* Homewood, Illinois: Goodheart-Willcox Company, 1969.

C. Billiet, Walter E., and Leslie F. Goings. *Automotive Electrical Systems.* Third Edition. Chicago, Illinois: American Technical Society, 1970.

D. Toboldt, William K., and Puruis, Jud. *Motor Services Automotive Encyclopedia.* Homewood, Illinois: Goodheart-Willcox Company, 1965.

ALTERNATOR CHARGING CIRCUITS
UNIT VI

INFORMATION SHEET

I. Terms and definitions

A. Rotor--Wire coil wrapped around an iron core and mounted on a rotating shaft

(NOTE: The rotor assembly does the same job for the alternator as the field coil and pole shoe do for the generator; however, the rotor assembly revolves.)

B. Stator--Laminated soft iron ring with three groups of coils

(NOTE: The stator assembly does the same job as the armature in a generator; however, the stator is fixed while the armature turns.)

C. Diode--Device that allows current to flow in one direction and blocks current in opposite direction

D. Slip rings--Metal conductors in the form of a ring, fastened to each end of coil and mounted on rotor shaft

(NOTE: Current flows through the regulator, through the insulated brush, through one slip ring into the coil, and out through the other slip ring and the other brush to ground.)

E. Short circuit--Wire touching another wire and providing a shorter path for current to flow

F. Open circuit--Circuit in which a wire is broken or disconnected

G. Grounded circuit--Circuit in which a wire touches ground causing the current to flow to ground instead of through the circuit

H. Transistorized regulator--Fully electronic unit composed of resistors, diodes, zener diode, transistors, and thermistor

I. Heat sink--Dissipates heat from diodes

(NOTE: High ampere alternators often use finned diodes for better heat removal.)

II. Purpose of the alternator charging circuit--The alternator charging circuit recharges the battery and maintains a supply of electrical current to meet the operating needs of the equipment

INFORMATION SHEET

III. Alternator charging circuit components and functions (Transparencies 1 and 2)

A. Battery

1. Starts the circuit by supplying spark to start engine
2. Helps out during peak operation when electrical load is too much for alternator
3. Stabilizes system voltage

B. Alternator

1. Supplies electrical power to accessory circuits
2. Recharges battery

C. Regulator--Limits the alternator voltage to a safe, preset value

D. Ammeter--Measures the rate of current flow

E. Voltmeter--Indicates produced voltage

F. Indicator lights--Indicates problems in system; used in place of a meter

IV. Major parts of an alternator (Transparency 3)

A. Drive end frame

B. Rotor assembly

C. Stator assembly

D. Slip ring end frame

E. Diodes

F. Brush assembly

G. Pulley

V. Differences between alternator and generator (Transparency 4)

A. Alternator

1. Rotates the field inside the stationary windings
2. Rectifies the AC current to DC with a series of diodes

INFORMATION SHEET

B. Generator

1. Rotates the windings (armature) inside the field

2. Rectifies AC current to DC through the use of a segmented commutator and brushes

VI. Advantages of an alternator as opposed to a generator

A. Produces higher output at lower engine speeds

B. Simplicity in construction requires less maintenance and space

VII. Reason alternator produces more current at low speed than a generator--Alternator has more pole pieces than the generator so that many more magnetic lines of force are cut during one revolution of the rotor

(NOTE: The alternator usually has fourteen pole pieces and the generator usually has two.)

VIII. Construction of the stator windings--Windings have three phases or groups of windings, with each winding connected to a positive and negative diode (Transparency 5)

IX. Control of alternator by regulator--Regulator places a resistance in the field circuit which reduces current flow to the alternator rotor

(NOTE: No current regulator is needed, since the alternator limits its output by setting its own opposing field during operation.)

X. Component parts of transistorized regulator and functions

A. Resistors--Devices made of wire or carbon which prevent a resistance to current flow

B. Zener diode--Diode connected in a reverse bias, which will conduct a reverse current beyond a predetermined voltage

C. Transistor--Semiconductors which control the flow of current by either allowing it to flow or stopping it

D. Thermistor--Temperature-compensated resistor whose degree of resistance varies with the temperature

(NOTE: It controls the zener diode so that a higher system voltage is produced in cold weather, when needed.)

INFORMATION SHEET

XI. Operation of transistorized regulator

A. Allows battery current to excite the alternator field coils

B. Controls charging voltage at safe values during operation

XII. Safety rules for working with alternator charging circuits

A. Never attempt to polarize the circuit

B. Be sure the battery is in good operating condition before making any tests or adjustments

C. Never operate the alternator in an open circuit, except when instructed in the technical manual

D. Never short or ground the alternator terminals

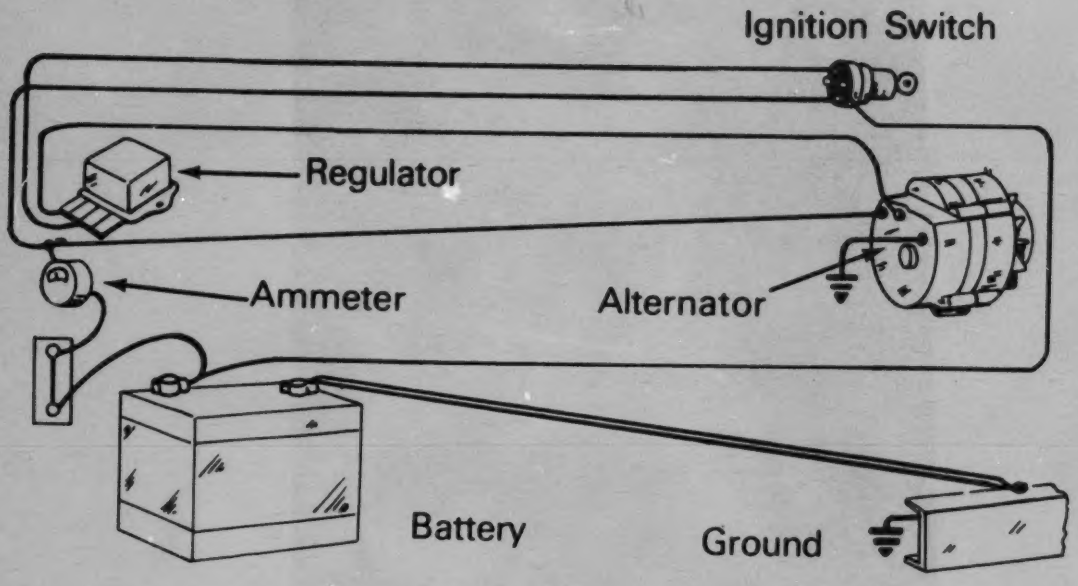
E. Do not disconnect the voltage regulator while the alternator is running

F. Disconnect the negative battery cable first when removing the alternator or battery

G. Do not use acid-core solder on the alternator terminals; use only a rosin-core solder

H. Never immerse the circuit components in cleaning solution

Alternator Charging Circuit Components



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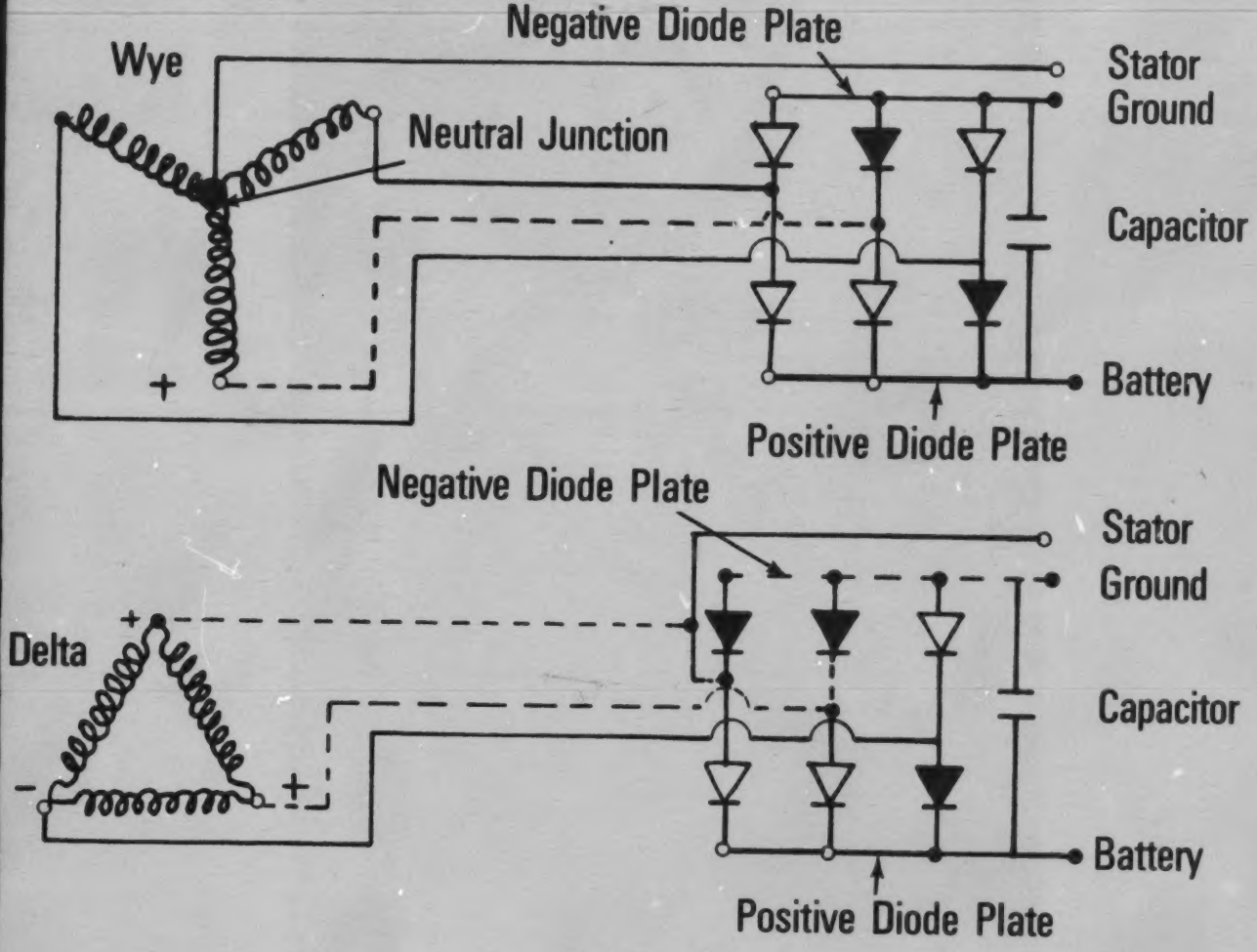
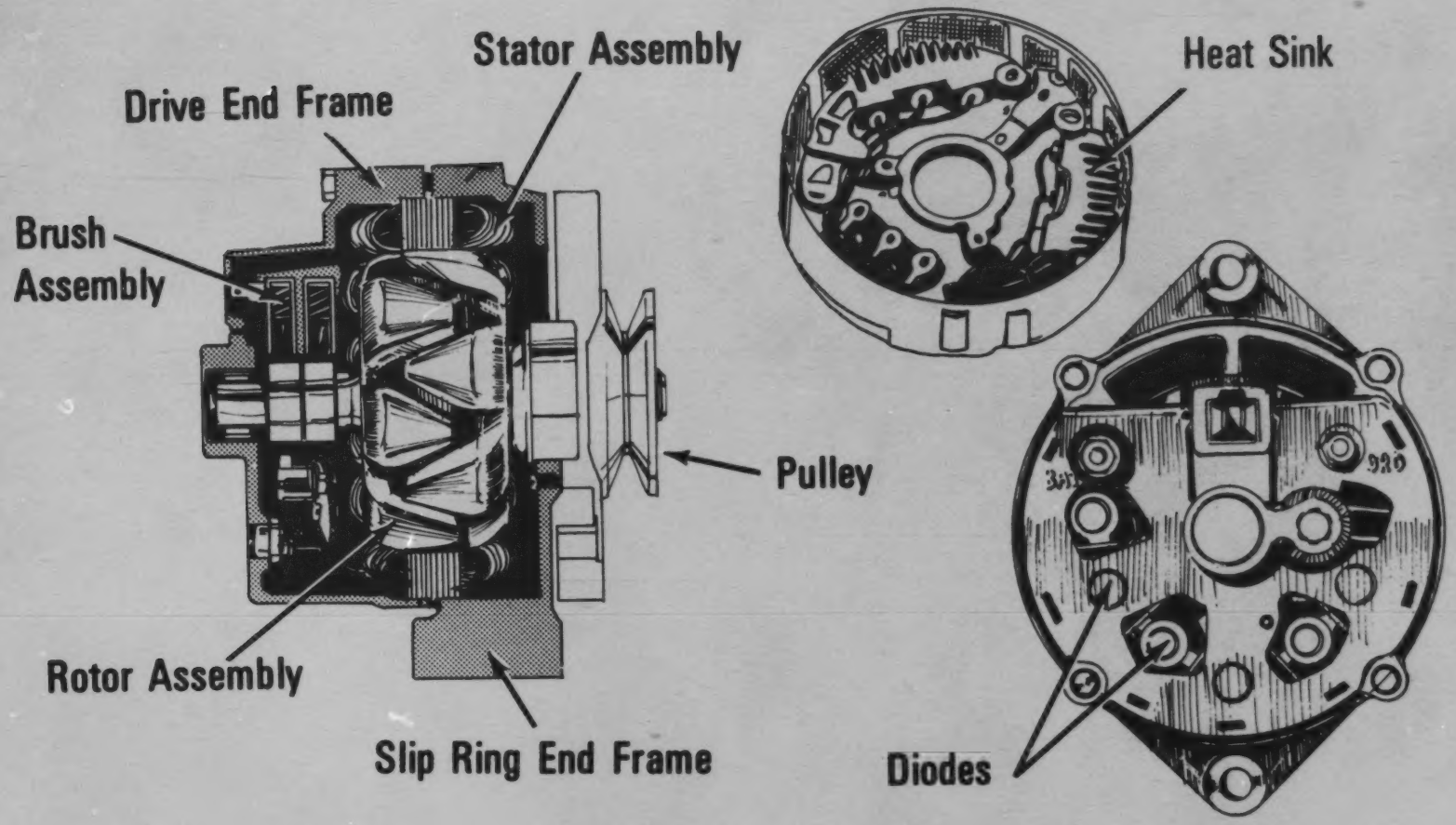
Alternator Circuit Schematic



Parts of the Alternator



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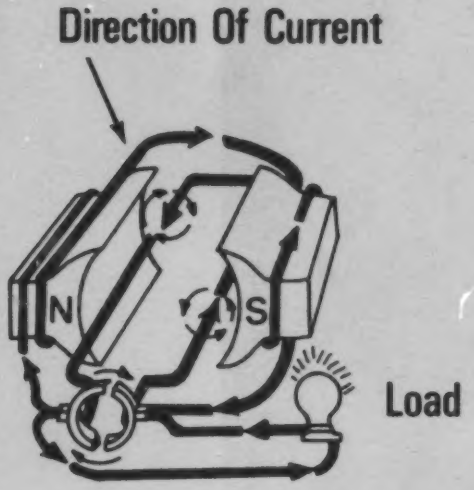
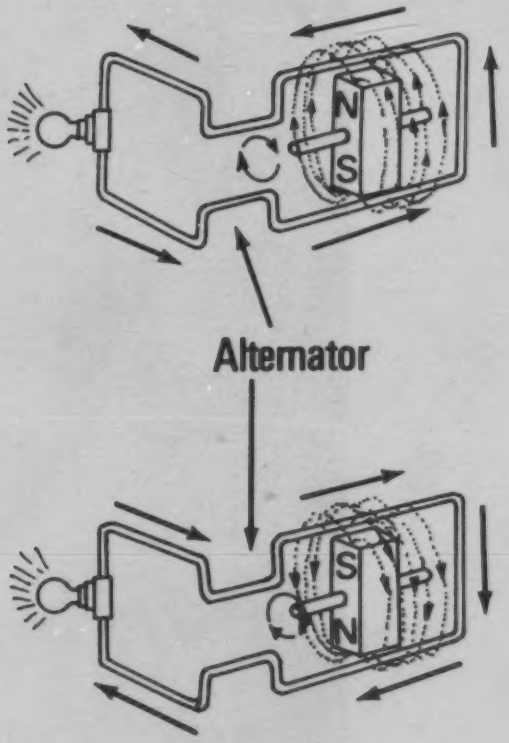
TM 3

D - 269-F

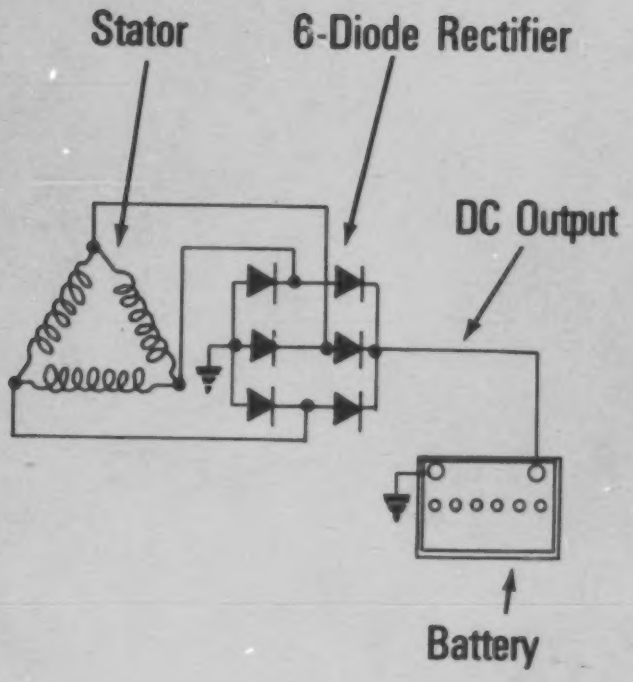
Differences In Alternator And Generator



DC Generator

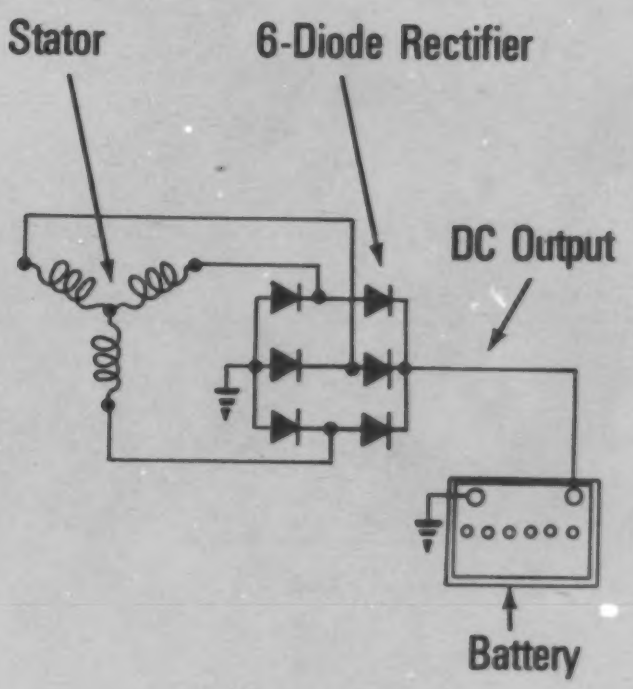


Stator Winding Construction



DELTA-CONNECTED STATOR WINDINGS

1061



"Y"-CONNECTED STATOR WINDINGS

1062

ALTERNATOR CHARGING CIRCUITS
UNIT VI

JOB SHEET #1--TEST THE ALTERNATOR CHARGING CIRCUIT AND REGULATOR

I. Tools and materials

A. Basic hand tool set

B. Voltmeter

C. Ammeter

D. Variable resistor

E. Jumper wire

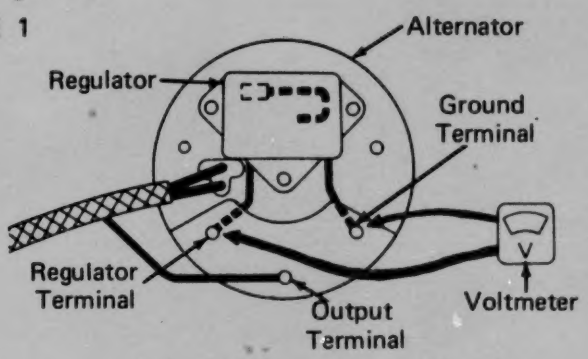
F. Safety glasses

II. Procedure

A. Perform test no. 1

1. Connect the voltmeter across the regulator terminal and ground terminal (Figure 1)

FIGURE 1



Voltmeter Test Connections

2. With the engine, ignition key switch, and accessories off, the voltmeter should read less than 0.1 volt

(NOTE: A high reading indicates a shorted isolation diode or ignition key switch.)

B. Perform test no. 2

1. Under the same conditions as test no. 1, turn the ignition key switch on

JOB SHEET #1

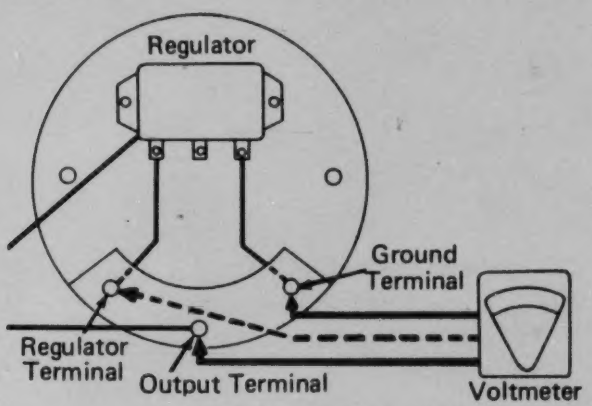
2. The voltmeter reading should be between 2 and 3 volts

(NOTE: A high reading could be caused by a high resistance in the alternator field, defective brushes, or a defective regulator. A low reading might indicate a shorted alternator field, a defective regulator, or an open circuit.)

C. Perform test no. 3

1. Leave the voltmeter connected to the ground terminal and regulator terminal of the alternator (Figure 2)

FIGURE 2



Voltmeter Connections

2. With the engine running and the key switch on but all accessories off, the voltmeter should read more than 15 volts

3. Move the voltmeter lead from the regulator terminal to the output terminal; the voltmeter should read 1 volt less

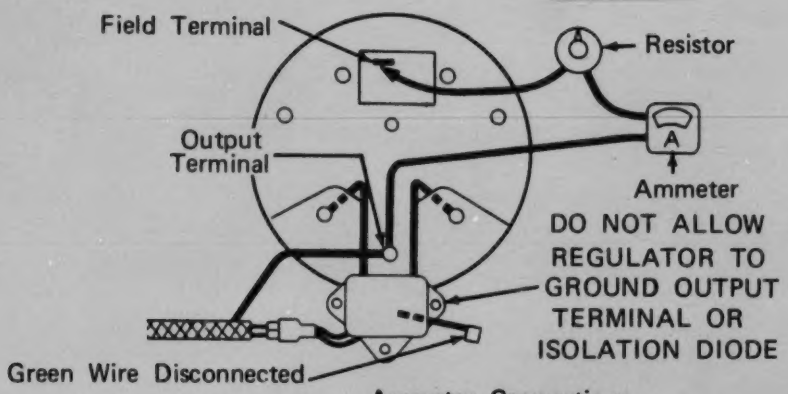
(NOTE: If the regulator terminal voltage is correct and the output terminal is the same as battery voltage, then the isolation diode is open.)

D. Perform test no. 4

(NOTE: This test is usually performed if test no. 2 indicated a malfunction.)

1. With the engine and switch off, disconnect the regulator-to-alternator field terminal wire (Figure 3)

FIGURE 3 JOB SHEET #1



Ammeter Connections

(NOTE: Let the regulator hang on the wires connected to the regulator and ground alternator terminals. Be very careful in how the regulator hangs. Do not allow it to ground on the output terminal.)

2. Connect the ammeter in series with a variable resistor to the field terminal and output terminal

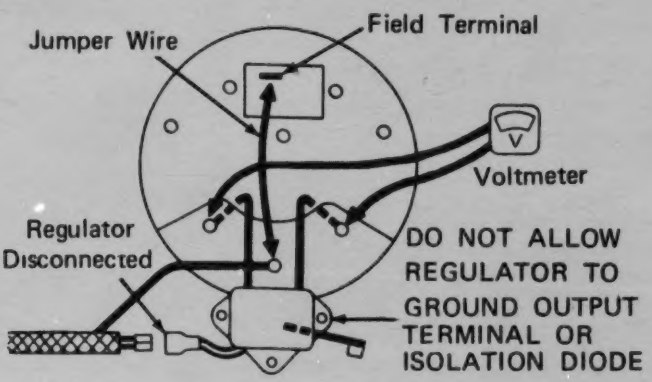
3. With all resistance eliminated, the ammeter should read 2.0 to 2.5 amps with the alternator cold

(NOTE: A high reading indicates a shorted field winding or brushes. A low reading means a high resistance in the brushes or slip ring, or an open circuit in the field windings.)

E. Perform test no. 5

1. Connect the voltmeter and jumper wire (Figure 4)

FIGURE 4



Jumper Wire And Voltmeter Connections

2. Run the engine at a specified speed

EXAMPLE: 800 RPM

JOB SHEET #1

3. This should give a voltmeter reading of 15 volts

(CAUTION: Do not allow voltage to go above 16.5 volts.)

(NOTE: If this test proved to be satisfactory, but test no. 3 voltage was below specifications, the regulator is probably at fault. If this test voltage was low, but tests no. 2 and 4 were satisfactory, the alternator is probably faulty.)

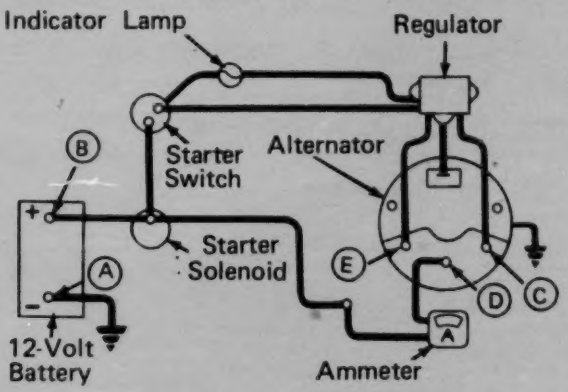
F. Test wiring resistance

(NOTE: If the alternator and regulator operate properly, check the wiring.)

1. Make a quick visual check of the lead connections and wires

2. Disconnect battery ground cable, then disconnect alternator output wire and connect ammeter (Figure 5)

FIGURE 5



Wiring Test Points

3. Connect ground cable and run engine to obtain a 10-amp charging rate

4. With a voltmeter, check the voltage at different points (Figure 5)

5. The voltage between these points should be as follows:

Test Points	Max. Voltage
A-C	0.3 volts
B-D	0.3 volts
B-E	1.3 volts

JOB SHEET #1

6. Always disconnect battery ground cable to prevent accidental grounding while connecting the alternator output terminal wire

7. Reconnect battery ground cable

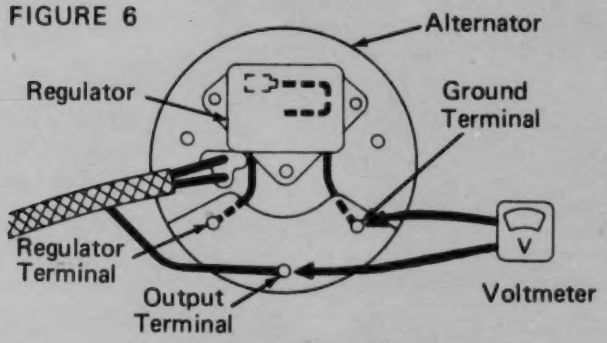
(NOTE: A high reading indicates a high resistance in the wiring or components.)

G. Test regulator

1. Connect the voltmeter (Figure 6)

(NOTE: Use an accurate voltmeter, one that will measure to within plus or minus 0.1 volts.)

FIGURE 6



Regulator Test Connections

2. Run the engine to obtain a 10-amp charging rate for about 15 minutes to stabilize the regulator temperature

3. Measure the regulator temperature about one inch from the regulator and check the voltmeter reading

4. Compare the reading with manufacturer's specifications

(NOTE: If the voltage is not within limits, the regulator is faulty.)

ALTERNATOR CHARGING CIRCUITS
UNIT VI

JOB SHEET #2--REMOVE AND REPLACE AN ALTERNATOR

I. Tools and materials

A. Basic hand tool set

B. Belt tension gauge

C. Battery cable clamp removal tool

D. Shop towels

E. Safety glasses

II. Procedure

A. Remove battery ground cable

B. Remove wire leads from alternator

(NOTE: The battery lead on the alternator will be dangerous to remove unless the battery ground cable has been removed from the battery. Alternator leads should be tagged for replacement.)

C. Remove the alternator belt adjusting bolt

D. Move the alternator toward the engine

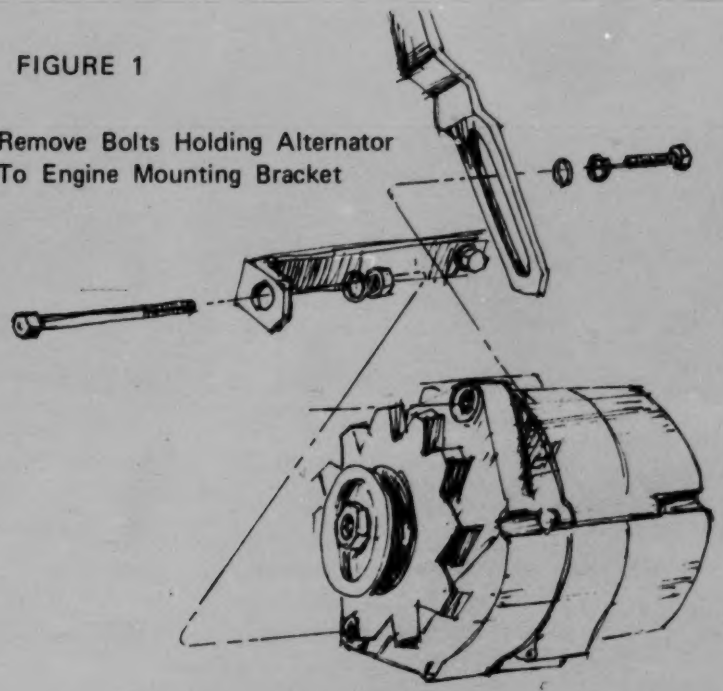
E. Remove the alternator belt from the alternator pulley

JOB SHEET #2

F. Remove the bolts holding the alternator to the engine mounting bracket (Figure 1)

FIGURE 1

Remove Bolts Holding Alternator To Engine Mounting Bracket



G. Lift the alternator out of the bracket

H. Service alternator as required

I. To replace, position the alternator in the engine mounting bracket

J. Start alternator retaining bolts and tighten securely

K. Position alternator belt on pulley and move alternator away from engine to tighten belt

L. Pry the alternator away from the engine to adjust the alternator belt tension

(NOTE: Use caution when adjusting the alternator belt to avoid damaging the alternator. Refer to manufacturer's recommendations for tightening procedures.)

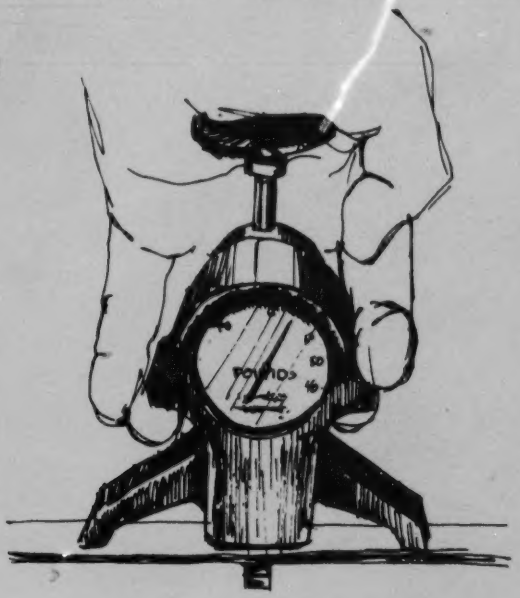
M. Install the alternator adjusting bolt

JOB SHEET #2

N. Check alternator belt tension with a belt tension gauge and adjust to manufacturer's specifications (Figure 2)

(NOTE: The alternator belt must be adjusted properly.)

FIGURE 2



Check Belt For Tightness

O. Install wire leads that were removed from the alternator and tighten securely

P. Install battery ground cable

(NOTE: Never attempt to polarize an alternator.)

ALTERNATOR CHARGING CIRCUITS
UNIT VI

JOB SHEET #3--DISASSEMBLE, TEST, AND REASSEMBLE AN ALTERNATOR

I. Tools and materials

A. Basic hand tool set

B. Alternator pulley removal tools

C. Alternator diode removal equipment

D. Alternator testing equipment

E. Torque wrench

F. Shop towels

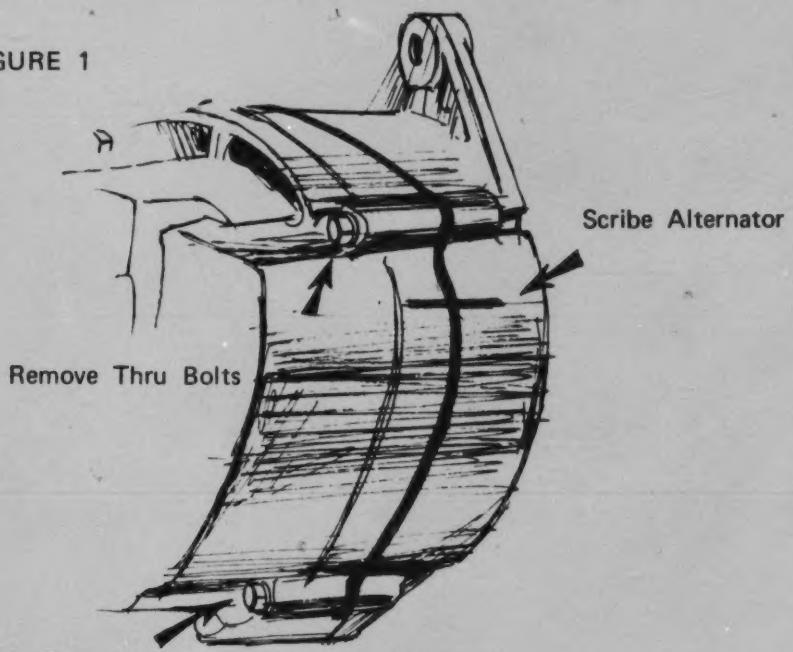
G. Safety glasses

II. Procedure

A. Disassemble alternator

1. Scribe the alternator before disassembly (Figure 1)

FIGURE 1



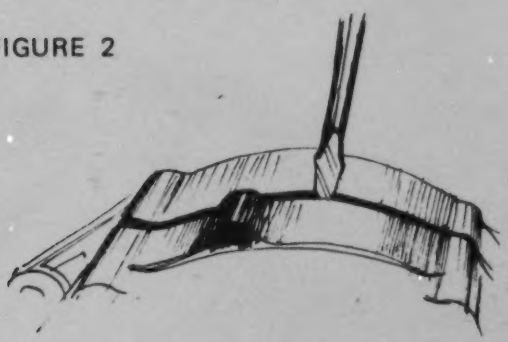
2. Remove thru bolts holding the end frames together

JOB SHEET #3

3. Pry at bolt locations to separate the drive end frame from the slip ring end frame (Figure 2)

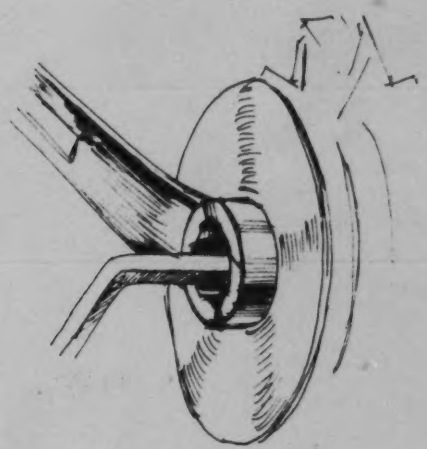
   (NOTE: Be sure stator stays with slip ring end of frame.)

FIGURE 2



4. Remove the slip ring end frame and stator (as an assembly) from drive end frame and rotor assembly
5. Remove the three stator lead attaching nuts
6. Separate stator from slip ring end frame
7. Remove screws, brushes, and brushholder assembly
8. Remove heat sink from end frame
9. Remove pulley retaining nut (Figure 3)

FIGURE 3



Remove Pulley Retaining Nut

JOB SHEET #3

10. Remove pulley and fan using pullers as required

11. Remove rotor and spacers from end frame assembly

12. Remove drive frame bearing retainer and bearing from drive end frame

B. Service and test alternator

1. Wash all metal parts except stator, diode, and rotor assemblies

2. Clean bearings and inspect for pitting or roughness

3. Replace bearings as required

4. Inspect rotor slip rings

(NOTE: The slip rings should be clean and free of scratches.)

5. Service as required

6. Inspect brushes for wear

7. Replace brushes as required

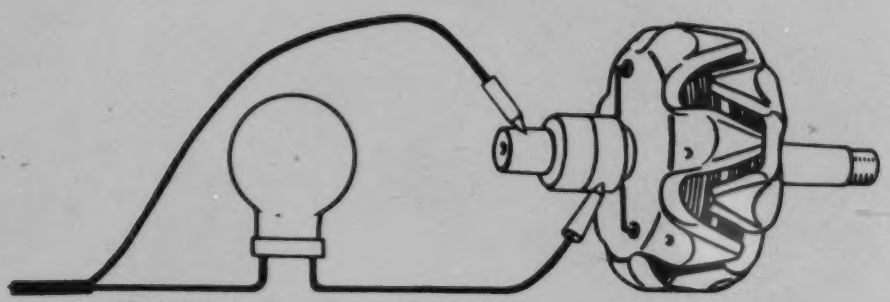
8. Test the rotor for grounds (Figure 4)

a. Connect one lead of a test lamp from either slip ring to the rotor shaft

b. Observe test light

(NOTE: If test lamp lights, the rotor is grounded.)

FIGURE 4



Test Rotor For Grounds

JOB SHEET #3

9. Test the rotor for open circuit (Figure 5)

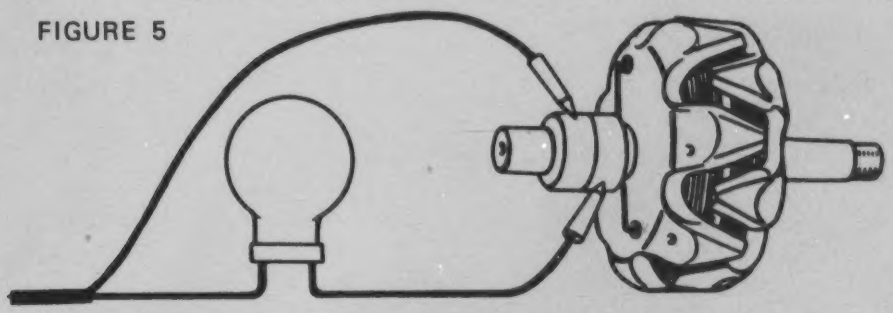
   a. Connect one lead of a test lamp to one slip ring and the other lead to the remaining slip ring

      (NOTE: Test on side of rims to keep from damaging surfaces.)

   b. Observe the test lamp

      (NOTE: If the test lamp does not light, the circuit is open.)

FIGURE 5



Test Rotor For Opens

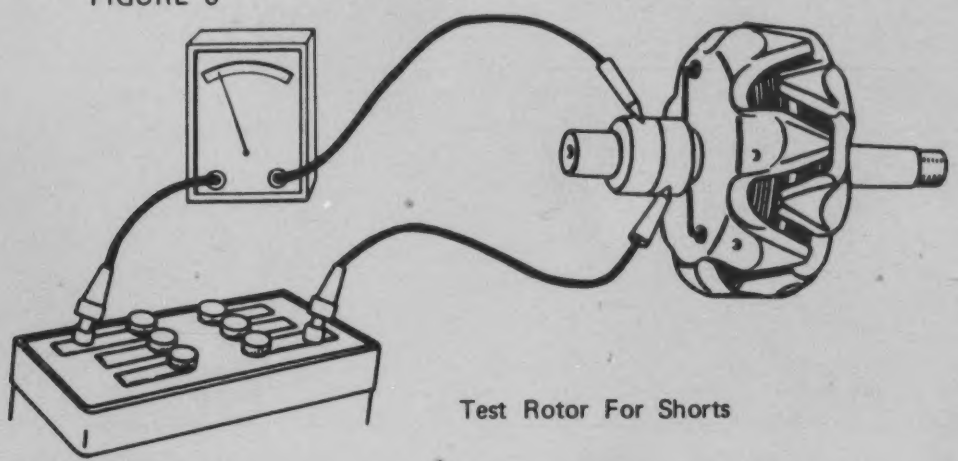
10. Test the rotor for short circuit (Figure 6)

   a. Connect a twelve-volt battery and ammeter in series with the two slip rings

   b. Read the ammeter

      (NOTE: An ammeter reading above specified field amperage draw indicates a short circuit. Refer to manufacturer's specifications.)

FIGURE 6



Test Rotor For Shorts

JOB SHEET #3

11. Test the stator for grounds (Figure 7)

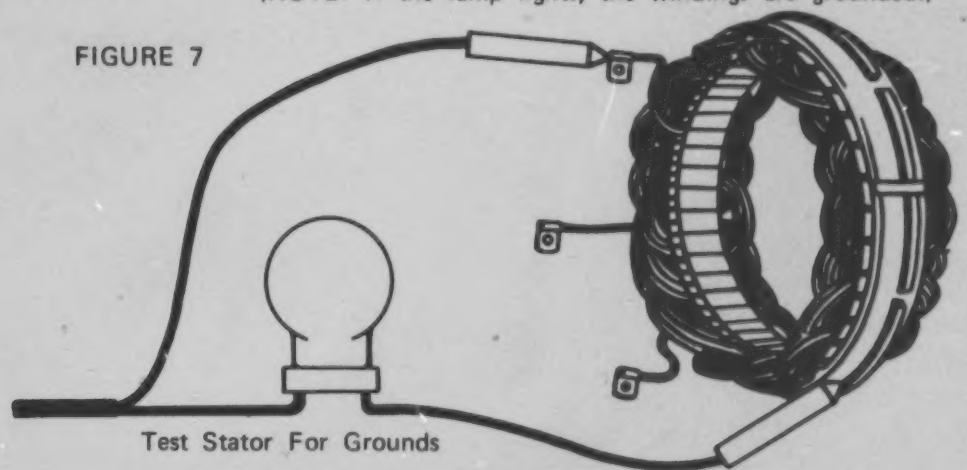
(NOTE: Stators can be checked for ground only through output tests.)

a. Connect one lead of a test lamp to the stator frame

b. Connect the other lead to any stator lead

(NOTE: If the lamp lights, the windings are grounded.)

FIGURE 7



Test Stator For Grounds

12. Test the stator for open circuit (Figure 8)

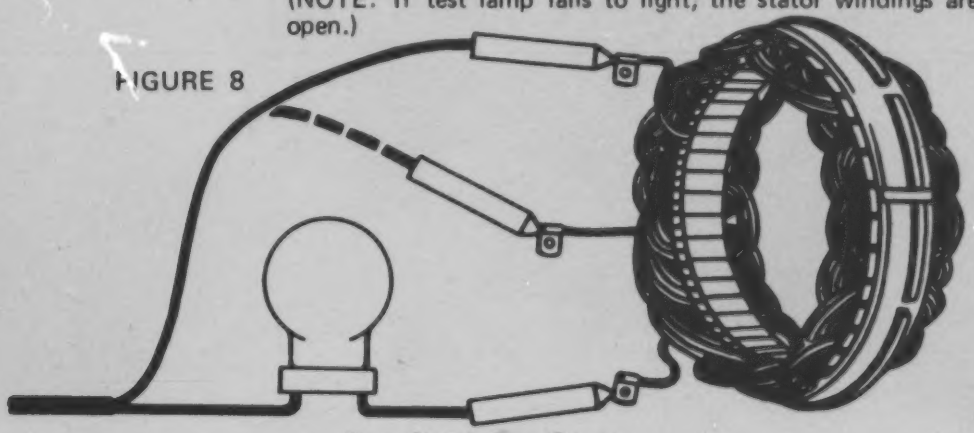
(NOTE: This test will not work on a delta wound stator.)

a. Connect a test lamp between each pair of stator leads

b. Observe the test lamp

(NOTE: If test lamp fails to light, the stator windings are open.)

FIGURE 8



Test Stator For Opens

JOB SHEET #3

13. Test heat sink diodes

(NOTE: If a test lamp is used instead of an ohmmeter, voltage should be 12 volts or less.)

a. Zero ohmmeter if used

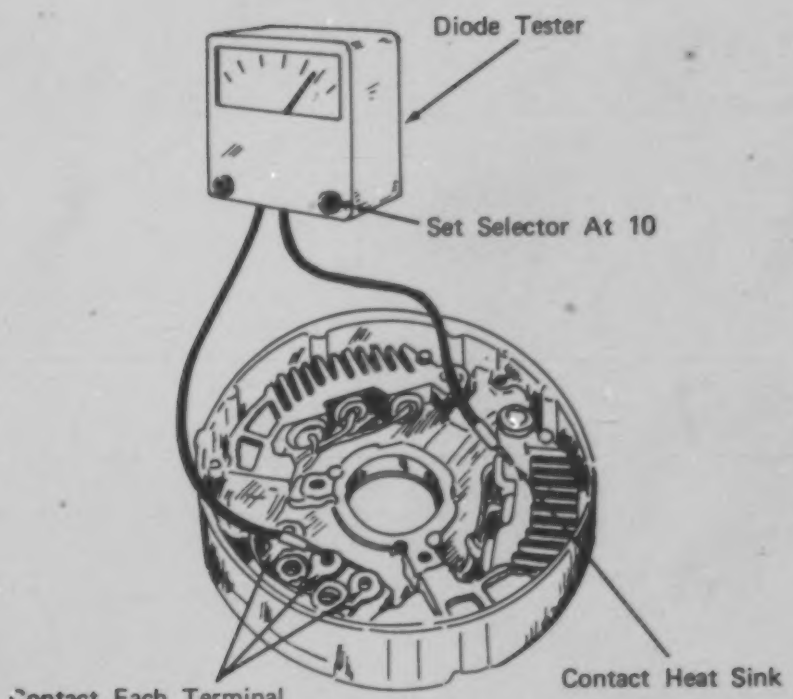
b. Test positive diodes (Figure 9)

1) Touch one lead or probe to positive heat sink

2) Touch one lead to stator lead terminals one at a time

3) Reverse leads to check flow in opposite direction

FIGURE 9



Diode Test

JOB SHEET #3

14. Test the end frame diodes

    a. Connect one lead of a twelve-volt test lamp to end frame

    b. Connect the other lamp lead to the diode lead

    (NOTE: If lamp lights in both directions or fails to light at all, the diode is defective.)

    c. Replace any parts found defective

    d. Replace any diodes found defective

    NOTE: Use proper diode removal and replacement tools.)

15. Replace slip ring end frame bearing assembly, if grease supply is exhausted

    (NOTE: Make no attempt to relubricate and reuse bearings.)

16. Repack drive end bearings with proper lubricant

C. Reassemble alternator

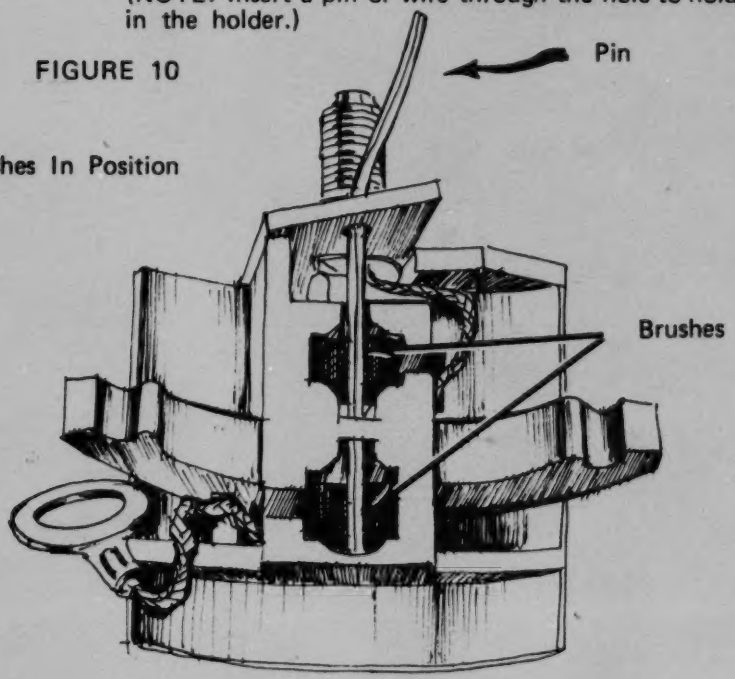
1. Assemble heat sink to end frame

2. Install brush holder and brushes into slip ring end frame (Figure 10)

(NOTE: Insert a pin or wire through the hole to hold the brushes in the holder.)

FIGURE 10

Brushes In Position



JOB SHEET #3

3. Install stator assembly in slip ring end frame and locate diode connectors over the relay, diode, and stator leads

4. Install and tighten terminal nuts securely

5. Install bearing in drive end frame

6. Install rotor in drive end frame

7. Install fan, spacer, pulley, and retaining nut

8. Tighten nut to manufacturer's specifications

9. Assemble slip ring, end frame, and stator assembly to drive end frame and rotor assembly

   (NOTE: Align end frames by referring to scribe marks put on during disassembly.)

10. Install thru bolts in the end frame assembly

11. Tighten bolts securely

12. Remove wire holding brushes in place

13. Check alternator operation

ALTERNATOR CHARGING CIRCUITS
UNIT VI

JOB SHEET #4--TEST AND REPAIR A TRANSISTORIZED REGULATOR

I. Tools and materials

A. Basic hand tool set

B. Voltmeter

C. Carbon pile resistor

D. Ammeter

E. Jumper wire

F. Safety glasses

II. Procedure

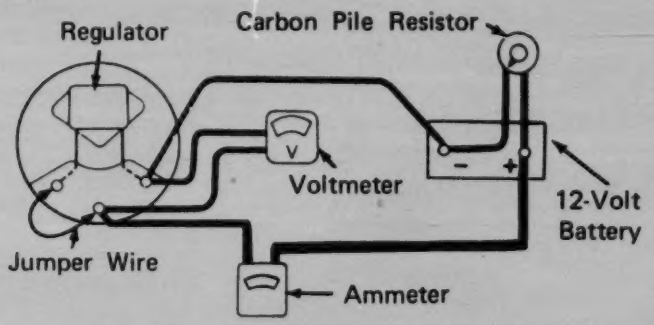
(NOTE: For a particular test procedure always follow the equipment technical manual.)

A. Test regulator voltage

(NOTE: This test can be performed either on or off the machine. Use an alternator that is known to be in good repair.)

1. Set up the test circuit (Figure 1)

FIGURE 1



Voltage Test For Transistorized Regulator

2. Connect a voltmeter to the alternator ground and output terminals (Figure 1)

(NOTE: Be sure to use a voltmeter with an accuracy within 0.1 volts.)

JOB SHEET #4

3. Start the engine, momentarily connect jumper wire to excite the field, and apply a load of about 10 amperes (use lights, motors, carbon pile resistors, etc.)

4. Operate the circuit for about 15 minutes to stabilize the temperature of the regulators

5. Measure and record the temperature about one inch from the regulator case

6. Compare the voltmeter reading with the voltage specifications listed in the machine technical manual

7. Adjust the reading for the temperature recorded above

B. Adjust and repair and transistorized regulator

1. Use adjusting screw to change the operating voltage for different conditions

(NOTE: This may not be used on some transistorized regulators.)

2. Since most transistorized regulators are sealed units, repair by replacing if they are found faulty

(NOTE: This type of regulator is usually more reliable than other kinds.)

ALTERNATOR CHARGING CIRCUITS
UNIT VI

NAME_____

TEST

1. Match terms on the right to the correct definitions.

_____a.	Wire coil wrapped around an iron core and mounted on a rotating shaft	1.	Open circuit
_____b.	Laminated soft iron ring with three groups of coils	2.	Diode
_____c.	Device that allows current to flow in one direction and blocks current in opposite direction	3.	Transistorized regulator
_____d.	Metal conductors in the form of a ring, fastened to each end of coil and mounted on rotor shaft	4.	Rotor
_____e.	Wire touching another wire and providing a shorter path for current to flow	5.	Stator
_____f.	Circuit in which a wire is broken or disconnected	6.	Heat sink
_____g.	Circuit in which a wire touches ground causing the current to flow to ground instead of through the circuit	7.	Grounded circuit
_____h.	Fully electronic unit composed of resistors, diodes, zener diodes, transistors, and thermistor	8.	Short circuit
_____i.	Dissipates heat from diodes	9.	Slip rings

2. State the purpose of the alternator charging circuit.

3. Match the alternator charging circuit components on the right to the correct functions.

_____a. Starts the circuit by supplying spark to start engine, helps out during peak operation when electrical load is too much for alternator, and stabilizes system voltage

_____b. Measures the rate of current flow

_____c. Supplies electrical power to accessory circuits and recharges battery

_____d. Indicates produced voltage

_____e. Limits the alternator voltage to a safe, preset value

_____f. Indicates problems in system; used in place of a meter

1. Indicator lights
2. Ammeter
3. Alternator
4. Regulator
5. Battery
6. Voltmeter

4. Identify the major parts of an alternator.

a. _____

b. _____

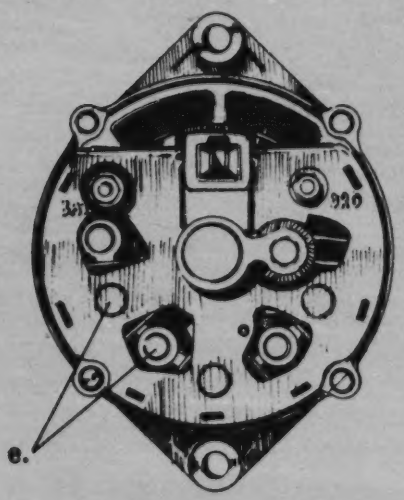
c. _____

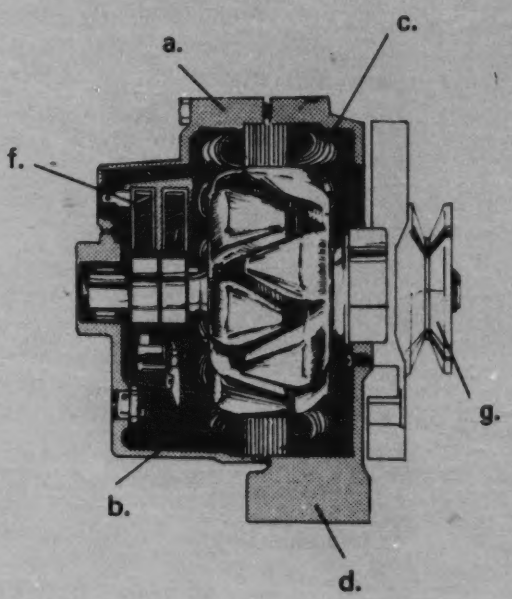
d. _____

e. _____

f. _____

g. _____





5. Explain the differences between an alternator and a generator.

   a. Alternator

      1)

      2)

   b. Generator

      1)

      2)

6. List two advantages of an alternator as opposed to a generator.

   a.

   b.

7. Explain why the alternator produces more current at low speed than a generator.

8. Discuss the construction of the stator windings.

9. Discuss how the alternator is controlled by the regulator.

10. Match the component parts of a transistorized regulator on the right to the correct functions.

_____a. Devices made of wire or carbon which prevent a resistance to current flow	1.	Transistor
_____b. Diode connected in a reverse bias, which will conduct a reverse current beyond a predetermined voltage	2.	Thermistor
	3.	Resistors
	4.	Zener diode

_____c. Semiconductors which control the flow of current by either allowing it to flow or stopping it

_____d. Temperature-compensated resistor whose degree of resistance varies with the temperature

11. Discuss the operation of the transistorized regulator.

12. List five safety rules for working with an alternator charging circuits.

a.

b.

c.

d.

e.

13. Demonstrate the ability to:

a. Test the alternator charging circuit and regulator.

b. Remove and replace an alternator.

c. Disassemble, test, and reassemble an alternator.

d. Test and repair a transistorized regulator.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

ALTERNATOR CHARGING CIRCUITS
UNIT VI

ANSWERS TO TEST

1. a. 4 e. 8 i. 6
   b. 5 f. 1
   c. 2 g. 7
   d. 9 h. 3

2. The alternator charging circuit recharges the battery and maintains a supply of electrical current to meet the operating needs of the equipment

3. a. 5
   b. 2
   c. 3
   d. 6
   e. 4
   f. 1

4. a. Drive end frame
   b. Rotor assembly
   c. Stator assembly
   d. Slip ring end frame
   e. Diodes
   f. Brush assembly
   g. Pulley

5. Explanation should include:
   a. Alternator
      1) Rotates the field inside the stationary windings
      2) Rectifies the AC current to DC with a series of diodes

b. Generator

1) Rotates the windings (armature) inside the field

2) Rectifies AC current to DC through use of a segmented commutator and brushes

6. a. Produces higher output at lower engine speeds

b. Simplicity in construction requires less maintenance and space

7. Explanation should include--Alternator has more pole pieces than the generator so that many more magnetic lines of force are cut during one revolution of the rotor

8. Discussion should include--Windings have three phases or groups of windings, with each winding connected to a positive and negative diode

9. Discussion should include--Regulator places a resistance in the field circuit which reduces current flow to the alternator rotor

10. a. 3

b. 4

c. 1

d. 2

11. Discussion should include:

a. Allows battery current to excite the alternator field coils

b. Controls charging voltage at safe values during operation

12. Any five of the following:

a. Never attempt to polarize the circuit

b. Be sure the battery is in good operating condition before making any tests or adjustments

c. Never operate the alternator in an open circuit, except when instructed in the technical manual

d. Never short or ground the alternator terminals

e. Do not disconnect the voltage regulator while the alternator is running

f. Disconnect the negative battery cable first when removing the alternator or battery

g. Do not use acid-core solder on the alternator terminals; use only a rosin-core solder

h. Never immerse the circuit components in cleaning solution

13. Performance skills evaluated to the satisfaction of the instructor.

OPERATION AND MAINTENANCE
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to list the major duties of an engine operator and the inspections to include in a checklist before starting an engine and during the normal operation. The student should also be able to match the cause to the corrective action when an engine fails to start, when an engine fails to come up to speed, and when the engines misfire. This knowledge will be evidenced by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Define terms associated with operation and maintenance.
2. List four major duties of an engine operator.
3. List inspections to include in a checklist before starting a diesel engine.
4. List inspections to include in a checklist during normal operation.
5. List factors to include in the procedure for stopping a diesel engine.
6. Name two performance records that should be maintained.
7. Match the causes of engines being hard to start or will not start to the corrective actions.
8. Match the causes of an engine failing to come up to speed to the corrective actions.
9. Match the causes of an engine misfiring to the corrective actions.
10. List causes of engine knock.
11. List causes of an overheated engine.
12. List four causes of smokey exhaust.

OPERATION AND MAINTENANCE
UNIT I

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information sheet.

C. Discuss unit and specific objectives.

D. Discuss information sheet.

E. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Test

D. Answers to test

II. Reference--Kates, Edgar J., and Luck, William E. *Diesel and High Compression Gas Engines.* Chicago: American Technical Soceity, 1974.

OPERATION AND MAINTENANCE
UNIT I

INFORMATION SHEET

I. Terms and definitions

- A. Symptom--Subjective evidence of mechanical trouble
- B. Log--Form for keeping engine operating and accountability records
- C. Checklist--Series of inspection points for determining if maintenance or servicing is needed

II. Major duties of an engine operator

- A. Starting engine
- B. Normal running of engine
- C. Stopping engine
- D. Record maintenance

III. Inspections before starting engine

- A. Cooling system
- B. Lubricating system
- C. Fuel system
- D. Starting system
  1. Air supply
  2. Fuel supply
  3. Compression

(NOTE: Immediately after starting, check the lubricating oil pressure, cooling water flow, and fuel supply. Watch entire engine to see if all parts function properly. Run at light load, if possible, until it reaches operating temperature.)

INFORMATION SHEET

IV. Inspections during normal operation

A. Inspect engine frequently

B. Watch loading

C. Regulate jacket water temperature (if used)

D. Keep lubrication system clean

E. Check combustion conditions

(NOTE: Do this on larger engines by taking firing pressure readings through use of indicator cards or pyrometer.)

F. Listen to the engine

V. Stopping procedure

A. Make sure starting equipment is fully charged

B. Check to see that all pressures and temperatures are normal

C. Take load off engine gradually

D. Let engine idle until temperature falls

E. Shut off fuel injection

(NOTE: If independent water pump or oil pump are used keep in circulation for about 15 minutes.)

VI. Performance records

A. Operating records

(NOTE: Typical record form or log should include cooling water and exhaust temperatures, turbocharger pressure, lube-oil pressure, and temperature, electrical, and load date.)

B. Accounting records

(NOTE: Typical record form or log should include what the plant produces in terms of kilowatt-hours, water pumped, and ton-miles pulled; and what the plant used in terms of fuel, lube oil, operating labor, supplies, parts, and repair labor.)

INFORMATION SHEET

VII. Causes of engines being hard to start or will not start and corrective actions

A. Not enough fuel--Check fuel tanks, be sure all valves are open, check transfer pump, clean air filters

B. Air in fuel line-- Prime and vent pump and piping

C. Water or dirt in fuel--Drain fuel system and clean tank

D. Starting valves out of order (if used)--Make sure starting valve is not stuck open or leaking

E. Low compression--Check for improper valve seating, stuck piston rings, cylinder head or valve cage gaskets leaking

F. Cranking speed too low--Charge or replace battery, service starter

G. Fuel injection improperly timed--Time injection to manufacturer's specifications

VIII. Causes of an engine failing to come up to speed and corrective actions

A. Not enough fuel--Adjust governor or throttle controls; check for air or water in fuel

B. Fuel nozzles dirty or clogged--Clean or replace nozzles

C. Injection pump valves leak--Regrind or replace valve and seat assemblies

D. Low compression--Check for improper inlet or exhaust valve seating, cylinder head or valve cage gaskets leaking, compression release not in position

E. Engine overloaded--If electrical load, open switches; if mechanical load open (dump) clutch

F. Too much friction--Eliminate cause of excess friction

IX. Causes of an engine misfiring and corrective actions

A. Water or dirt in fuel--Drain and refill with clean fuel

B. Gasoline in diesel fuel--Drain and refill with proper fuel

C. Air in fuel system--Bleed the system

INFORMATION SHEET

D. Poor nozzle operation--Clean and check nozzle spray pattern

E. Faulty injection pump--Check and calibrate the fuel injection pump

F. Nozzles not seated properly--Reposition nozzles and tighten retaining screws to specified torque

X. Causes of engine knock

A. Injector valves sticking; broken valve spring

B. Fuel timing wrong

C. Inlet or exhaust valve sticking

D. Poor quality fuel; dirt or water in fuel

E. Worn bearings; excessive valve tappet clearance

(NOTE: Pounding may be caused by loose crankpin, excessive clearance in wrist pin; excessive clearance, liner-to-piston.).

XI. Causes of an overheated engine

A. Overload

B. Poor cooling

C. Late combustion

D. Lubrication inadequate

E. Hot bearings

XII. Causes of smokey exhaust

A. Engine overloaded (fuel to air ratio)

B. Poor combustion

C. Excessive lubrication

D. Clogged air cleaners

OPERATION AND MAINTENANCE
UNIT I

NAME_____

TEST

1. Define terms associated with operation and maintenance.

   a. Symptom--

   b. Log--

   c. Checklist--

2. List four major duties of an engine operator.

   a.

   b.

   c.

   d.

3. List three inspections to include in a checklist before starting a diesel engine.

   a.

   b.

   c.

4. List four inspections to include in a checklist during normal operation.

   a.

   b.

   c.

   d.

5. List four steps to include in the procedure for stopping a diesel engine.

   a.

   b.

   c.

   d.

6. Name two performance records that should be maintained.

   a.

   b.

7. Match the causes of engines being hard to start or will not start on the right to the corrective actions on the left.

_____a.	Check fuel tanks, be sure all valves are open, check transfer pump, clean air filters	1.	Low compression
_____b.	Prime and vent pump and piping	2.	Starting valves out of order (if used)
_____c.	Drain fuel system and clean tank	3.	Fuel injection improperly timed
_____d.	Make sure starting valve is not stuck open or leaking	4.	Cranking speed too low
_____e.	Check for improper valve seating, stuck piston rings, cylinder head or valve cage gaskets leaking	5.	Water or dirt in fuel
_____f.	Charge or replace battery, service starter	6.	Not enough fuel
_____g.	Time injection to manufacturer's specification	7.	Air in fuel line

8. Match the causes of an engine failing to come up to speed on the right to the corrective actions on the left.

_____a. Adjust governor or throttle controls; check for air or water in fuel	1. Low compression
_____b. Clean or replace nozzles	2. Not enough fuel
_____c. Regrind or replace valve and seat assemblies	3. Fuel nozzles dirty or clogged
_____d. Check for improper inlet or exhaust valve seating, cylinder head or valve cage gaskets leaking, compression release not in position	4. Injection pump valves leak
_____e. If electrical load, open switches; if mechanical load open (dump) clutch	5. Too much friction
_____f. Eliminate cause of excess friction	6. Engine overloaded

9. Match the causes of an engine misfiring on the right to the corrective actions on the left.

_____a. Drain and refill with clean fuel	1. Faulty injection pump
_____b. Drain and refill with proper fuel	2. Air in fuel system
_____c. Bleed the system	3. Nozzles not seated properly
_____d. Clean and check nozzle spray pattern	4. Water or dirt in fuel
_____e. Check and calibrate the fuel injection pump	5. Poor nozzle operation
_____f. Reposition nozzles and tighten retaining screws to specified torque	6. Gasoline in diesel fuel

10. List four causes of engine knock.

a.

b.

c.

d.

11. List four causes of an overheated engine.

a.

b.

c.

d.

12. List four causes of smokey exhaust.

a.

b.

c.

d.

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OPERATION AND MAINTENANCE
UNIT I

ANSWERS TO TEST

1. a. Symptom--Subjective evidence of mechanical trouble

   b. Log--Form for keeping engine operating and accountability records

   c. Checklist--Series of inspection points for determining if maintenance or servicing is necessary

2. a. Starting engine

   b. Normal running of engine

   c. Stopping engine

   d. Record maintenance

3. Any three of the following:

   a. Cooling system

   b. Lubricating system

   c. Fuel system

   d. Starting system

      1) Air supply

      2) Fuel supply

      3) Compression

4. Any four of the following:

   a. Inspect engine frequently

   b. Watch loading

   c. Regulate jacket water temperature (if used)

   d. Keep lubrication system clean

   e. Check combustion conditions

   f. Listen to the engine

5. Any four of the following:
   a. Make sure starting equipment is fully charged
   b. Check to see that all pressures and temperatures are normal
   c. Take load off engine gradually
   d. Let engine idle until temperature falls
   e. Shut off fuel injection

6. a. Operating records
   b. Accounting records

7. a. 6
   b. 7
   c. 5
   d. 2
   e. 1
   f. 4
   g. 3

8. a. 2
   b. 3
   c. 4
   d. 1
   e. 6
   f. 5

9. a. 4
   b. 6
   c. 2
   d. 5
   e. 1
   f. 3

10. Any four of the following:
    a. Injector valves sticking; broken valve spring
    b. Fuel timing wrong
    c. Inlet or exhaust valve sticking
    d. Poor quality fuel; dirt or water in fuel
    e. Worn bearings; excessive valve tappet clearance

11. Any four of the following:
    a. Overload
    b. Poor cooling

c. Late combustion

d. Lubrication inadequate

e. Hot bearings

12. a. Engine overloaded (fuel to air ratio)

b. Poor combustion

c. Excessive lubrication

d. Clogged air cleaners

DIAGNOSIS AND TESTING OF ENGINES
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to list basic steps to follow in diagnosing an engine malfunction or failure. The student should also be able to list major check points when inspecting and operating and complete a diesel troubleshooting guide. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with diagnosis and testing of engines to the correct definitions.
2. List seven steps in diagnosing and testing an engine.
3. List four major checkpoints when inspecting a diesel engine.
4. List major checks to make when operating the engine.
5. List tests that are made with a dynamometer.
6. Name three factors necessary for the engine to produce horsepower.
7. Select the possible causes of a diesel engine being hard to start or will not start.
8. Select the possible causes of a diesel engine starting but not running.
9. Select the items which would cause a diesel engine to misfire.
10. Select the items which would cause a diesel engine to knock.
11. Select the items which would cause a diesel engine to overheat.
12. Select the items which would cause a diesel engine to have lack of power.
13. Select the items which would cause a diesel engine to use too much oil.

14. Name causes of high oil pressure.

15. List causes of low oil pressure.

16. Complete a diesel troubleshooting guide.

17. Demonstrate the ability to:

    a. Load test an engine with a dynamometer.

    b. Test engine cylinder compression.

    c. Check air intake system for restriction.

    d. Check crankcase pressure, exhaust back pressure, and air box pressure.

DIAGNOSIS AND TESTING OF ENGINES
UNIT II

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information, assignment, and job sheets.

C. Discuss unit and specific objectives.

D. Discuss information and assignment sheets.

E. Demonstrate and discuss the procedures outlined in the job sheets.

F. Explain how to properly use and read a mercury and a water-filled manometer.

G. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete assignment and job sheets.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Assignment Sheet #1--Complete a Diesel Troubleshooting Guide

D. Answers to assignment sheet

E. Job sheets

1. Job Sheet #1--Load Test an Engine with a Dynamometer

2. Job Sheet #2--Test Engine Cylinder Compression

3. Job Sheet #3--Check Air Intake System for Restrictions

4. Job Sheet #4--Check Crankcase Pressure, Exhaust Back Pressure, and Air Box Pressure

F. Test

G. Answers to test

II. References:

A. Toboldt, Bill. *Diesel: Fundamentals, Service, Repair.* South Holland, Illinois: Goodheart-Willcox Company, 1973.

B. Kates, Edgar J., and Luck, William E. *Diesel and High Compression Gas Engines.* Chicago: American Technical Society, 1974.

C. *Fundamentals of Service: Engines.* Moline, Illinois: Deere and Company, 1972.

D. *Service Manual, Detroit Diesel Engines.* Detroit, Michigan: Detroit Diesel Allison, 1975.

E. *Cummins Engine Company Shop Manual.* Columbus, Indiana: Cummins Engine Company, 1974.

DIAGNOSIS AND TESTING OF ENGINES
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Diagnosis--In engine service, the use of instruments to troubleshoot the engine parts to locate the cause of failure

B. Dynamometer-Instrument for measuring the power output of an engine by applying a load to the engine, thereby testing the horsepower and torque

C. Vacuum gauge--Instrument used to check the air intake system of an engine

(NOTE: A vacuum gauge measures pressure of liquids and gases.)

D. Manometer--Instrument using mercury or water in a U-tube, indicating positive or negative (vacuum) pressure by the difference in height of the two columns

E. Tachometer--Device measuring speed of rotation

F. Pyrometer--Instrument for measuring temperatures beyond the range of a mercurial thermometer

II. Steps in diagnosing and testing an engine

A. Know the system

(NOTE: Study technical manuals, how engine works, knowledge of three basic needs: fuel-air mixture, compression, and ignition.)

B. Ask the operator

(NOTE: Ask operator what warning signs preceeded the trouble; what previous work has been done on the engine; has similar trouble occurred before.)

C. Operate the machine

D. Inspect the machine

(NOTE: Check all fluid levels.)

E. List the possible causes

F. Reach a conclusion

G. Test your conclusion

INFORMATION SHEET

III. Major checkpoints

A. Water system

B. Oil system

C. Fuel system

D. Electrical system

(NOTE: Keep a list of all trouble signs noted from above checks.)

IV. Checks when operating an engine

A. Gauge readings

B. Unusual sounds (where? at what speed?)

C. Smells (any signs of unusual exhaust)

D. Smoke

E. Controls

F. Power under load

G. Idle speed

H. Battery condition

I. Alternator or generator output

V. Tests made with a dynamometer

A. Engine horsepower

B. Exhaust smoke analysis

C. Fuel consumption

D. Crankcase blow-by

E. Air cleaner restriction

F. Oil pressure

G. Clutch operation

INFORMATION SHEET

H. Exhaust temperature

I. Air box pressure

J. Exhaust pressure

VI. Factors necessary to produce horsepower

A. Fuel-air mixture

B. Compression

C. Ignition

VII. Causes of a diesel engine being hard to start or will not start

A. No fuel or improper fuel

B. Water or dirt in fuel or dirty filters

C. Air in fuel system

D. Low cranking speed

E. Faulty nozzle operation

F. Improper timing

G. Faulty injection pump

VIII. Causes if diesel engine starts but will not run

A. Dirt in fuel

B. Air restrictions

C. Clogged filter

IX. Causes of diesel engine misfiring

A. Water or dirt in fuel

B. Gasoline in diesel fuel

C. Air in fuel system

D. Faulty nozzle operation

E. Faulty injection pump

INFORMATION SHEET

F. Nozzles not seated properly in cylinder head

G. Low compression

X. Causes of diesel engine knock

A. Improper injection pump timing

B. Worn engine bearings or bushings

C. Excessive crankshaft end play

D. Loose bearing caps

E. Foreign material in cylinder

F. Scored piston

G. Faulty injection nozzle

H. Bad fuel

XI. Causes of diesel engine overheating

A. Defective radiator cap

B. Radiator fins bent or plugged

C. Defective thermostat

D. Insufficient coolant

E. Loose fan belt

F. Cooling system limed up

G. Overloaded engine

H. Faulty engine timing

I. Engine low on oil

J. Wrong type of fuel

K. Faulty water pump

L. Faulty shutter operation (if used)

M. Faulty nozzles

N. Fan problems

INFORMATION SHEET

XII. Causes of a diesel engine having lack of power

A. Air cleaner dirty or otherwise obstructed

B. Restricted air flow in intake system

C. Restriction in fuel lines or filters

D. Wrong type of fuel

E. Valve failure

F. Incorrect valve tappet clearance

G. Low engine speed

H. Crankcase oil too heavy

I. Low compression

J. Low operating temperature

K. Faulty injection pump delivery

L. Exhaust restriction

M. Incorrect camshaft timing

XIII. Causes of a diesel engine using too much oil

A. Crankcase oil too light

B. Worn pistons and rings

C. Worn valve guides or stem oil seals

D. Loose connecting rod bearings

E. External oil leaks

F. Oil pressure too high

G. Engine speed too high

H. Crankcase ventilator pump not working

I. Restricted air intake or breather

J. Excessive oil in rocker arm assembly

INFORMATION SHEET

XIV. Causes of high oil pressure

A. Stuck relief valve

B. Defective pressure gauge

C. Wrong oil pump

D. Oil to thick

XV. Low oil pressure

A. Worn bearings

B. Poor relief valve seating

C. Too light oil

D. Worn oil pump

E. Engine low on oil

F. Loose connection or leaky seals at oil filter, pump, or cooler

G. Defective oil pressure gauge

H. Dilution of oil

DIAGNOSIS AND TESTING OF ENGINES
UNIT II

ASSIGNMENT SHEET #1--COMPLETE A DIESEL TROUBLESHOOTING GUIDE

The following questions provide a guide for beginning analysis of troubleshooting a diesel.

Select the method on the right that would most likely answer the question.

____ 1) Is acceleration normal?

____ 2) How does it start when cold?

____ 3) How does it start when hot?

____ 4) Is there any misfiring?

____ 5) Under what condition does it misfire?

____ 6) Is exhaust normal?

____ 7) Does the engine surge at any speed?

____ 8) Is there any oil leakage?

____ 9) Is there any coolant leakage?

____10) Is there any fuel leakage?

____11) Is there any air leakage from turbocharger or blower?

____12) Does the engine run hot?

____13) When was the last service work performed?

____14) What work was done on the engine?

____15) Under what conditions is the engine operated?

____16) Are any knocks apparent?

____17) Under what conditions are the knocks apparent?

a. Ask operator

b. Visual inspection

c. Operate engine

d. Compression gauge

e. Dynamometer test

f. Pyrometer (if used)

ASSIGNMENT SHEET #1

____18) What is operating temperature of individual cylinder exhaust?

____19) Is exhaust gas analysis normal?

____20) Is there any restriction in air duct? Any leakage?

____21) What is the compression pressure of various cylinders?

____22) Has the brand of fuel been changed recently?

DIAGNOSIS AND TESTING OF ENGINES
UNIT II

ANSWERS TO ASSIGNMENT SHEET

1.	a	12.	c
2.	a	13.	a
3.	a	14.	a
4.	a, c	15.	a
5.	a	16.	a, c
6.	c	17.	a, c
7.	a, c	18.	f
8.	b	19.	e
9.	b	20.	b, e
10.	b	21.	d
11.	b	22.	a

DIAGNOSIS AND TESTING OF ENGINES
UNIT II

JOB SHEET #1--LOAD TEST AN ENGINE
WITH A DYNAMOMETER

I. Tools and materials

A. Basic hand tool set

B. Live engine

C. Dynamometer

D. Engine technical manual

E. Dynamometer instruction manual

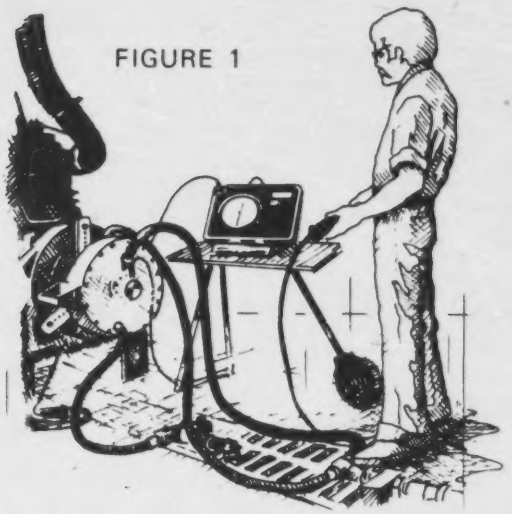
F. Safety glasses

II. Procedure

A. Connect the engine to the dynamometer using the manufacturer's instructions (Figure 1)

(CAUTION: Rotating parts are a safety hazard.)

FIGURE 1



Portable Dynamometer

JOB SHEET #1

B. Operate the engine at about one-half load until the coolant and crankcase oil temperatures are up to normal

(NOTE: Warm up will take about 30 minutes, but is very important to a good test. Keep close check on engine oil pressure and temperature during test.)

C. Gradually increase the load on the engine until its speed is reduced to rated load speed as given in the engine technical manual

D. Read the horsepower on the dynamometer

(NOTE: On some models a conversion chart or calculator is required to find horsepower. Horsepower can be affected by testing conditions such as altitude, humidity, and temperature.)

E. Compare the horsepower with that given in the engine technical manual

(NOTE: Do not expect engines to always equal these specifications. If the engine rates much lower than normal, this is a signal that service is needed.)

F. While the engine is operating under load, note the outlet of the crankcase ventilating system

G. Remove the crankcase oil filter cap if too much vapor appears

(NOTE: If an excessive amount of vapor or smoke appears here as well as at the vent, there is blow-by in the engine cylinders and they must be reconditioned before the engine will perform at its best.)

H. Check engine technical manual for specified amount of engine vapor flow

(NOTE: Any increase in flow over the specified amount indicates crankcase blow-by.)

I. Recondition the engine for good operation if the blow-by is excessive

(NOTE: Even though the engine develops its rated horsepower using a normal amount of fuel, a tune-up may still improve its efficiency. Consider both hours of operation and the conditions under which the engine has been operated. It is far more economical in the long run to tune the engine before a lack of performance makes it mandatory.)

DIAGNOSIS AND TESTING OF ENGINES
UNIT II

JOB SHEET #2--TEST ENGINE CYLINDER COMPRESSION

I. Tools and materials

A. Basic hand tool set

B. Compression gauge

C. Live engine

D. Safety glasses

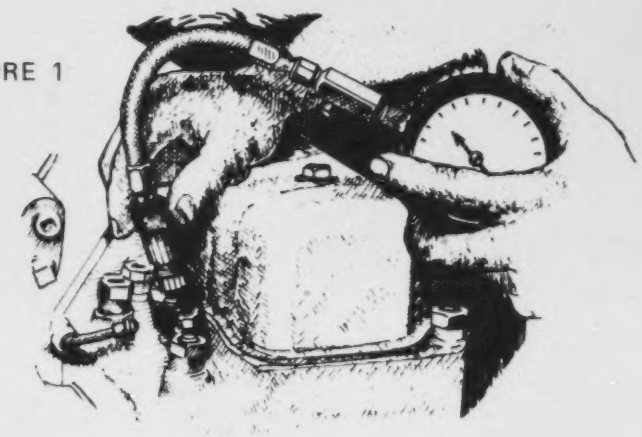
II. Procedure

A. Warm up the engine to operating temperature

B. Remove the energy cells injectors, or injection nozzles

C. Connect a pressure gauge to the cylinder port (Figure 1)

FIGURE 1



D. Set the engine speed control to stop position

E. Turn the engine with the starter until the pressure gauge registers no further rise in pressure

(NOTE: It is a good practice to count the number of compression strokes, indicated by movement of the gauge needle, and check each cylinder with the same number of strokes. The engine must be at full cranking speed or as specified in appropriate service manual to get a good reading.)

JOB SHEET #2

F. Check the pressure reading against the engine technical manual

(NOTE: Low pressure indicates leakage through valves, rings, or gaskets. Variations in cylinder pressures of more than 10% usually indicate a need for cylinder reconditioning.)

DIAGNOSIS AND TESTING OF ENGINES
UNIT II

JOB SHEET #3--CHECK AIR INTAKE SYSTEM FOR RESTRICTION

I. Tools and materials

A. Basic hand tool set

B. Live engine

C. Water filled manometer

(NOTE: A vacuum gauge can also be used to make this check.)

D. Pipe tee

E. Shop towels

F. Safety glasses

II. Procedure

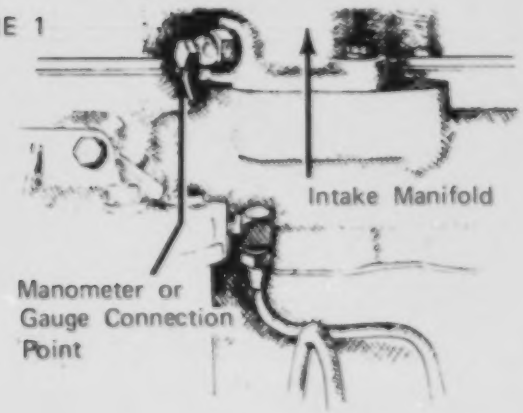
A. Check air intake system for restriction on a naturally aspirated engine

1. Connect manometer to manifold that does not have a restriction indicator

a. Connect manometer to side of intake manifold near middle of manifold (Figure 1)

(NOTE: If a plug is not provided in the manifold intake area, make reading as close to engine as possible in intake piping.)

FIGURE 1



JOB SHEET #3

b. Start engine and bring to normal operating temperature and governed speed

c. Check the normal air inlet vacuum at various speeds (no load)

d. Compare results with the engine technical manual operating specifications

2. Connect manometer to manifold with restriction indicator

a. Remove the indicator

b. Install a pipe tee fitting

c. Reinstall the indicator

d. Connect the gauge to the tee fitting

e. Start engine and bring to normal operating temperature and governed speed

f. Check the normal air inlet vacuum at various speeds (no load)

g. Compare results with the engine technical manual operating specifications

3. Check the operation of the air restriction indicator, if used

a. Use a board or metal plate to slowly cover the air intake opening

b. Note the action of the indicator in relation to the reading on the gauge

c. Replace indicator if it does not operate properly

B. Check air intake system for restriction on a turbocharged engine

1. Connect manometer to air intake pipe

(NOTE: Connection should be made about 2" upstream from turbocharger inlet, in a straight section of pipe.)

2. Start engine and bring to normal operating temperature and at governed speed

JOB SHEET #3

3. Measure the restriction when engine is under full load

   (NOTE: On some engines you may remove the air cleaner and ducting and note the gauge readings at various speeds; the difference between the two readings, with and without the air cleaner and ducting, is the actual restriction caused by the air cleaning and ducting.)

4. Compare results with the engine technical manual operating specifications

DIAGNOSIS AND TESTING OF ENGINES
UNIT II

JOB SHEET #4--CHECK CRANKCASE PRESSURE, EXHAUST BACK PRESSURE, AND AIR BOX PRESSURE

I. Tools and materials

A. Basic hand tool set

B. Live engine

C. Water filled manometer

D. Mercury filled manometer

E. 1/8" pipe plug

F. Small tap and die set

G. Shop towels

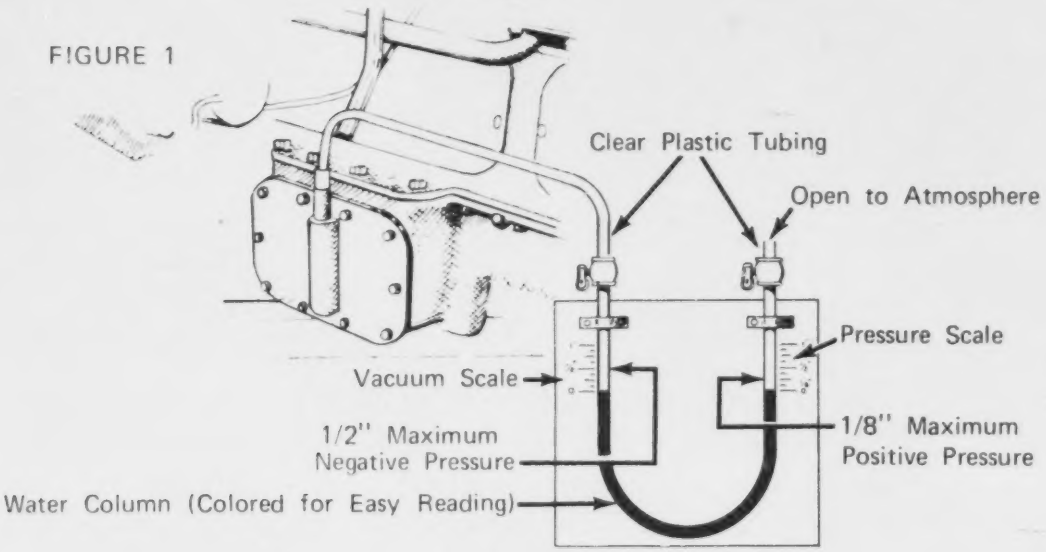
H. Safety glasses

II. Procedure

A. Check crankcase pressure

1. Connect water manometer to the oil dipstick opening in the cylinder block (Figure 1)

FIGURE 1



JOB SHEET #4

2. Operate the engine at manufacturer's rated load speeds and note the readings obtained

3. Compare the readings to specifications in the engine technical manual operating conditions

B. Check exhaust back pressure

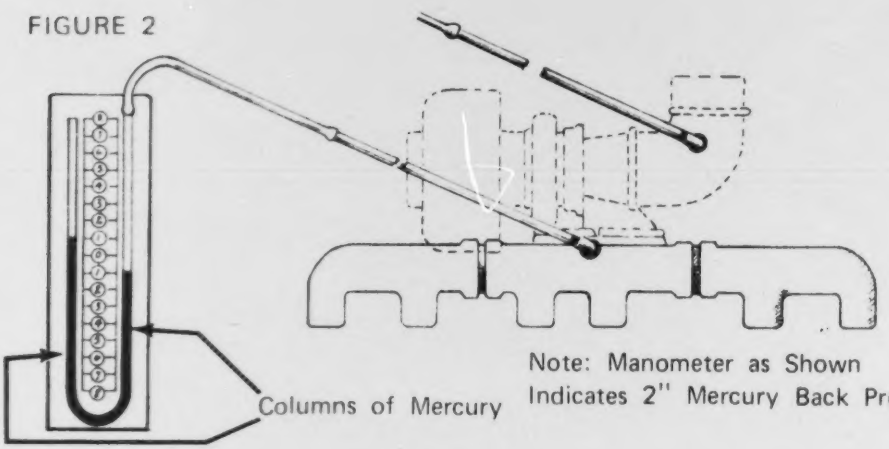
1. Remove 1/8" pipe plug in exhaust manifold

(NOTE: If no opening is provided, drill an 11/32" hole in exhaust manifold companion flange and tap the hole to accomodate a 1/8" pipe plug.)

2. Connect the mercury manometer to the exhaust manifold (Figure 2)

(NOTE: On turbocharged engines check the exhaust back pressure in the exhaust piping 6" to 12" from the turbine outlet.)

FIGURE 2



3. Start engine and operate to normal operating temperature

4. Take back-pressure readings when engine is developing rated horsepower at governed speed

JOB SHEET #4

5. Add reading of mercury in both columns for final figure(Figure 2)

   Example: If mercury is 1 inch high in left column and 1 inch low in right column, there is 2 inches of pressure; if mercury is 1 inch high in right column and 1 inch low in left column, there is 2 inches of vacuum

6. Check the engine technical manual operating conditions for maximum permissible back pressure

C. Check air box pressure

1. Connect manometer to an air box drain tube

2. Operate the engine at manufacturer's rated load speed and note pressure readings

3. Compare readings with the engine technical manual operating conditions

DIAGNOSIS AND TESTING OF ENGINES
UNIT II

NAME _____

TEST

1. Match the terms on the right to the correct definitions.

_____a.	In engine service, the use of instruments to troubleshoot the engine parts to locate the cause of failure	1. Vacuum gauge
_____b.	Instrument for measuring the power output of an engine by applying a load to the engine, thereby testing the horsepower and torque	2. Diagnosis
_____c.	Instrument used to check the air intake system of an engine	3. Tachometer
_____d.	Instrument using mercury or water in a U-tube, indicating positive or negative (vacuum) pressure by the difference in height of the two columns	4. Manometer
_____e.	Device measuring speed of rotation	5. Dynamometer
_____f.	Instrument for measuring temperatures beyond the range of a mercurial thermometer	6. Pyrometer

2. List seven steps in diagnosing and testing an engine.

a.

b.

c.

d.

e.

f.

g.

3. List four major checkpoints when inspecting a diesel engine.

   a.

   b.

   c.

   d.

4. List five major checks to make when operating the engine.

   a.

   b.

   c.

   d.

   e.

5. List six tests that are made with a dynamometer.

   a.

   b.

   c.

   d.

   e.

   f.

6. Name three factors necessary for the engine to produce horsepower.

   a.

   b.

   c.

7. Select the possible causes of a diesel engine being hard to start or will not start by placing an "X" in the appropriate blanks.

   _____a. Low cranking speed

   _____b. Faulty nozzle operation

   _____c. Cracked or eroded distributor rotor

   _____d. Defective coil or condenser

_____e. Air in fuel system

_____f. Improper timing

_____g. Water or dirt in fuel or dirty filters

_____h. Too heavy oil in air cleaner

_____i. No fuel or improper fuel

_____j. Faulty injection pump

8. Select the possible causes of a diesel engine starting but not running by placing an "X" in the appropriate blanks.

_____a. Dirt in fuel

_____b. Air restrictions

_____c. Clogged filter

_____d. Defective coil or condenser

9. Select the items which would cause a diesel engine to misfire by placing an "X" in the appropriate blanks.

_____a. Water or dirt in fuel

_____b. Gasoline in diesel fuel

_____c. Cracked distributor cap

_____d. Air in fuel system

_____e. Faulty nozzle operation

_____f. Faulty injection pump

_____g. Nozzles not seated properly in cylinder head

10. Select the items which would cause a diesel engine to knock by placing an "X" in the appropriate blanks.

_____a. Improper injection pump timing

_____b. Worn engine bearings or bushings

_____c. Excessive crankshaft end play

_____d. Loose bearing caps

_____e. Foreign material in cylinder

_____f. Restricted fuel line

11. Select the items which would cause a diesel engine to overheat by placing an "X" in the appropriate blanks.

_____a. Defective radiator cap

_____b. Radiator fins bent or plugged

_____c. Defective thermostat

_____d. Insufficient coolant

_____e. Loose fan belt

_____f. Cooling system limed up

_____g. Overloaded engine

_____h. Faulty engine timing

_____i. Distributor advance mechanism stuck

_____j. Engine low on oil

_____k. Wrong type of fuel

_____l. Faulty shutter operation (if used)

12. Select the items which would cause a diesel engine to have lack of power by placing an "X" in the appropriate blanks.

_____a. Air cleaner dirty or otherwise obstructed

_____b. Restricted air flow in intake system

_____c. Restriction in fuel lines or filters

_____d. Wrong type of fuel

_____e. Frost at fuel-lock strainer

_____f. Governor grinds

_____g. Distributor points burned

_____h. Incorrect camshaft timing

_____i. Low operating temperature

_____j. Faulty injection pump delivery

_____k. Improper hitching or belting of machine

_____l. Valve failure

_____m. Incorrect valve tappet clearance

_____n. Low engine speed

_____o. Crankcase oil too heavy

_____p. Low compression

13. Select the items which would cause a diesel engine to use too much oil by placing an "X" in the appropriate blanks.

_____a. Crankcase oil too light

_____b. Worn pistons and rings

_____c. Worn valve guides or stem oil seals

_____d. Loose connecting rod bearings

_____e. External oil leaks

_____f. Oil pressure too high

_____g. Engine speed too high

_____h. Crankcase ventilator pump not working

_____i. Restricted air intake or breather

_____j. Excessive oil in rocker arm assembly

_____k. Oil pressure too low

14. Name two causes of high oil pressure.

a.

b.

15. List five causes of low oil pressure.

a.

b.

c.

d.

e.

16. Complete a diesel troubleshooting guide.

17. Demonstrate the ability to:

a. Load test an engine with a dynamometer.

b. Test engine cylinder compression.

c. Check air intake system for restriction.

d. Check crankcase pressure, exhaust back pressure, and air box pressure.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

DIAGNOSIS AND TESTING OF ENGINES
UNIT II

ANSWERS TO TEST

1. a. 2
   b. 5
   c. 1
   d. 4
   e. 3
   f. 6
2. a. Know the system
   b. Ask the operator
   c. Operate the machine
   d. Inspect the machine
   e. List the possible causes
   f. Reach a conclusion
   g. Test your conclusion
3. a. Water system
   b. Oil system
   c. Fuel system
   d. Electrical system
4. Any five of the following:
   a. Gauge readings
   b. Unusual sounds (where? at what speed?)
   c. Smells (any signs of unusual exhaust)
   d. Smoke
   e. Controls

f. Power under load

g. Idle speed

h. Battery condition

i. Alternator or generator output

5. Any six of the following:

a. Engine horsepower

b. Exhaust smoke analysis

c. Fuel consumption

d. Crankcase blow-by

e. Air cleaner restriction

f. Oil pressure

g. Clutch operation

h. Exhaust temperature

i. Air box pressure

j. Exhaust pressure

6. a. Fuel-air mixture

b. Compression

c. Ignition

7. a, b, e, f, g, i, j

8. a, b, c

9. a, b, d, e, f, g

10. a, b, c, d, e

11. a, b, c, d, e, f, g, h, j, k, l

12. a, b, c, d, h, i, j, l, m, n, o, p

13. a, b, c, d, e, f, g, h, i, j

14. Any two of the following:

a. Stuck relief valve

b. Defective pressure gauge

c. Wrong oil pump

d. Oil to thick

15. Any five of the following:

a. Worn bearings

b. Poor relief valve seating

c. Too light oil

d. Worn oil pump

e. Engine low on oil

f. Loose connection or leaky seals at oil filter, pump, or cooler

g. Defective oil pressure gauge

h. Dilution of oil

16. Evaluated to the satisfaction of the instructor

17. Performance skills evaluated to the satisfaction of the instructor

TUNE-UP AND ADJUSTMENT
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to tune-up and service a diesel engine. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Define terms associated with tune-up and adjustment.
2. List five major items to include in a visual inspection checklist.
3. Demonstrate the ability to:
   a. Tune-up and service a diesel engine.
   b. Tune-up a Cummins diesel engine.
   c. Tune-up a General Motors diesel engine.
   d. Tune-up a Caterpillar diesel engine.

TUNE-UP AND ADJUSTMENT
UNIT III

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information and job sheets.

C. Discuss unit and specific objectives.

D. Discuss information sheet.

E. Demonstrate and discuss the procedures outlined in the job sheets.

F. Discuss procedures for stopping a "run-away" engine

G. Discuss three valve adjustment methods.

H. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete job sheets.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Job sheets

1. Job Sheet #1--Tune-Up and Service a Diesel Engine
2. Job Sheet #2--Tune-Up a Cummins Diesel Engine
3. Job Sheet #3--Tune-Up a General Motors Diesel Engine
4. Job Sheet #4--Tune-Up a Caterpillar Diesel Engine

D. Test

E. Answers to test

II. References:

A. Kates, Edgar J., and Luck, William E. *Diesel and High Compression Gas Engines.* Chicago: American Technical Society, 1974.

B. *Fundamentals of Service: Engines.* Moline, Illinois: Deere and Company, 1972.

C. *Service Manual, Detroit Diesel Engines.* Detroit, Michigan: Detroit Diesel Allison, 1975.

D. *Cummins Engine Company Shop Manual.* Columbus, Indiana: Cummins Engine Company, 1974.

E. *Engine Service Manual.* Peoria, Illinois: Caterpillar Tractor Company, 1972.

TUNE-UP AND ADJUSTMENT
UNIT III

INFORMATION SHEET

I. Terms and definitions

A. Tune-up--Process of making checks and minor adjustments to improve the operation of the engine

(NOTE: Some companies consider tune-up to be preventive maintenance.)

B. Service--To clean, inspect, adjust, lubricate, or repair a component or part as needed

C. Replace--To install a new or rebuilt component or part

II. Visual inspection checklist

(NOTE: Engine should be kept as clean as possible.)

A. Oil and water leakage

B. Electrical system

C. Cooling system

D. Air intake system

E. Fuel system

TUNE-UP AND ADJUSTMENT
UNIT III

JOB SHEET #1--TUNE-UP AND SERVICE A DIESEL ENGINE

I. Tools and materials

A. Basic hand tool set

B. Compression tester with adapters

C. Appropriate engine special tools

D. Torque wrench

E. Nozzle tester

F. Radiator and radiator cap tester

G. Thermostat tester

H. Dynamometer

I. Appropriate engine service manuals

J. Dynamometer technical manual

K. Battery service manual

L. Safety glasses

II. Procedure

(NOTE: In the spaces to the right of each step, indicate the action which was taken. Inspection is the preliminary step prior to either servicing or replacing the component. Serviced means that the component or component part has been cleaned, inspected, adjusted, lubricated or repaired as needed. Replaced means that new or rebuilt components or component parts have been installed.)

		Inspected	Serviced	Replaced
A.	Service air intake and exhaust system			
1.	Clean pre-cleaner (if used)	☐	☐	☐
2.	Remove and clean air cleaner	☐	☐	☐
3.	Swab out inlet pipe in air cleaner body	☐	☐	☐
4.	Inspect exhaust system and muffler	☐	☐	☐
5.	Check crankcase ventilating system for restrictions	☐	☐	☐

JOB SHEET #1

		Inspected	Serviced	Replaced
B.	Service basic engine			
1.	Recheck air intake for restrictions	☐	☐	☐
2.	Check radiator for air bubbles or oil indicating compression or oil leaks	☐	☐	☐
3.	Check for leakage at cylinder head gasket	☐	☐	☐
4.	Retighten cylinder head cap screws	☐	☐	☐
	(NOTE: Refer to appropriate job sheet or engine service manual.)	☐	☐	☐
5.	Adjust valve clearance	☐	☐	☐
	(NOTE: Refer to appropriate job sheet or engine service manual.)			
6.	Check compression pressure in each cylinder	☐	☐	☐
	(NOTE: Refer to appropriate job sheet or engine service manual.)			
C.	Service fuel system			
1.	Check fuel lines for leaks or restrictions	☐	☐	☐
2.	Clean fuel pump sediment bowl	☐	☐	☐
3.	Test fuel pump pressure	☐	☐	☐
	(NOTE: Refer to appropriate job sheet or engine service manual.)			
4.	Check speed control linkage	☐	☐	☐
5.	Service diesel fuel filters	☐	☐	☐
6.	Check diesel injection pump	☐	☐	☐

JOB SHEET #1

		Inspected	Serviced	Replaced
	(NOTE: Refer to appropriate job sheet or engine service manual.)			
7.	Check and clean diesel injection nozzles	☐	☐	☐
	(NOTE: Refer to appropriate job sheet or engine service manual.)			
8.	Bleed diesel fuel system	☐	☐	☐
9.	Check diesel injection pump timing	☐	☐	☐
	(NOTE: Refer to appropriate job sheet or engine service manual.)			
D.	Service lubrication system			
1.	Check operation of pressure gauge or light	☐	☐	☐
2.	Service oil filter	☐	☐	☐
3.	Check condition of crankcase oil	☐	☐	☐
4.	Check engine oil pressure	☐	☐	☐
E.	Service cooling system			
1.	Check water pump for leaks and excessive shaft end play	☐	☐	☐
2.	Inspect radiator hoses	☐	☐	☐
3.	Clean and flush cooling system	☐	☐	☐
4.	Test thermostat and pressure cap	☐	☐	☐
5.	Test radiator for leaks	☐	☐	☐
6.	Check condition of fan belt			
F.	Service electrical system			

JOB SHEET #1

		Inspected	Serviced	Replaced
1.	Service battery			
	a. Clean battery, cable, terminals, and battery box	☐	☐	☐
	b. Tighten battery cables and battery hold-down	☐	☐	☐
	c. Check specific gravity of electrolyte and add water to proper level	☐	☐	☐
	d. Make high discharge or load test of battery condition	☐	☐	☐
	(NOTE: Refer to appropriate job sheet or battery service manual.)			
2.	Service generator or alternator			
	a. Check belt tension	☐	☐	☐
	b. Test alternator or generator output	☐	☐	☐
	(NOTE: Refer to appropriate job sheet or engine service manual.)			
3.	Service starting circuit			
	a. Check safety starter switch	☐	☐	☐
	b. Check current draw of starting motor	☐	☐	☐
4.	Service clutch free travel--Check free travel at clutch pedal or lever (if used)	☐	☐	☐
	(NOTE: Refer to appropriate service manual.)			

JOB SHEET #1

	Inspected	Serviced	Replaced
G. Check engine performance by conducting a load test with a dynamometer (NOTE: Refer to appropriate job sheet or dynamometer technical manual.)	☐	☐	☐

TUNE-UP AND ADJUSTMENT
UNIT III

JOB SHEET #2--TUNE-UP A CUMMINS DIESEL ENGINE

I. Tools and materials

A. Basic hand tool set

B. Cummins special tools

C. Torque wrench

D. Thickness gauge

E. Cleaning solvent

F. Diesel fuel

G. Shop towels

H. Safety glasses

II. Procedure

A. Adjust injector

1. Remove hood if applicable

2. Remove valve cover

(NOTE: Check the inside of the covers for presence of water condensation.)

3. Loosen the injector rocker lever adjusting nut on all cylinders

4. Rotate engine until the first "VS" mark on the pulley or damper is aligned with the index mark on the housing

5. Use an inch/lb torque wrench and in a near continuous motion draw the injector adjusting screw to its specified torque

B. Adjust valve crosshead

1. Loosen the adjusting screw lock-nut and back off the adjusting screw one turn

2. Use light finger pressure at the rocker lever contact surface to hold crosshead in contact with the valve stem nearest the pushrod

3. Turn adjusting screw down until it contacts its mating valve stem

JOB SHEET #2

4. For new crosshead and guides, advance the adjusting screw 20° more to straighten the stem in its guide; worn crosshead may be advanced 30° to straighten the stem in its guide

5. Hold the adjusting screw in this position and tighten locknut to specified torque

C. Adjust valve

(NOTE: On engines equipped with compression release apparatus be sure that the shaft is properly adjusted before adjusting valves.)

1. Loosen rocker arm locknuts

2. Using a specified thickness gauge, turn the adjusting screw to obtain a good contact on the thickness gauge

3. Adjust both the intake and exhaust valves

4. Tighten locknuts

5. Bar engine over in direction of rotation and firing order, and set the rest of the injectors, crossheads and valves

6. Install valve covers

D. Check fuel pump filter screens

1. Remove cap

2. Lift screens out and inspect magnet for metal particles

(NOTE: Large particles show excessive wear in gear pump.)

3. Clean screen

4. Reinstall and torque to specified limits

E. Adjust engine idle speed

1. Low idle

a. Attach tachometer to the drive outlet on top of the fuel pump

JOB SHEET #2

b. Remove pipe plug from spring pack cover

c. Set engine idle to manufacturer's specifications

(NOTE: Engine idle speed may change when the housing fills with fuel.)

2. Adjust high idle

a. Attach tachometer to the drive outlet on top of the fuel pump

(NOTE: If high idle has to be changed, consult the appropriate shop manual or service bulletin.)

b. Shut engine down

c. Remove spring pack cover

d. Remove snap ring

e. Increase or decrease shims to regulate engine speed. Each .001 inch shim will increase or decrease engine speed by 2 rpm

(NOTE: Never set maximum speed to please an operator.)

3. Check pump operation

a. Check manifold pressure

1) Install gauge at the shut-off valve

2) Operate engine 400 rpm below governed speed

3) Accelerate to governed speed

4) Observe gauge for specified pressure

b. Check inlet restriction

1) Install vacuum gauge at gear pump inlet

2) Operate warmed up engine 5 minutes after installation of gauge

3) Observe gauge readings

(NOTE: Readings should not exceed 8" to 8.5" vacuum.)

JOB SHEET #2

c. Check suction side, air leakage

1) Shut down engine

2) Install sight gauge on pump inlet side and operate engine

3) Check for air bubbles

(NOTE: Bubbles indicate an air leak.)

TUNE-UP AND ADJUSTMENT
UNIT III

JOB SHEET #3--TUNE-UP A GENERAL MOTORS DIESEL ENGINE

I. Tools and materials

A. Basic hand tool set

B. Cleaning solvent

C. GM diesel special tune-up tools

D. Torque wrench

E. Thickness gauge

F. Shop towels

G. Diesel fuel

H. Engine service manual

I. Safety glasses

II. Procedure

A. Adjust exhaust valve clearance

1. Adjust valves on cold engine

a. Remove loose dirt from valve rocker cover

b. Remove the cover

c. Place governor speed control lever in the idle speed position

d. Position engine by rotating the crankshaft until the injector follower is fully depressed on the cylinder to be adjusted

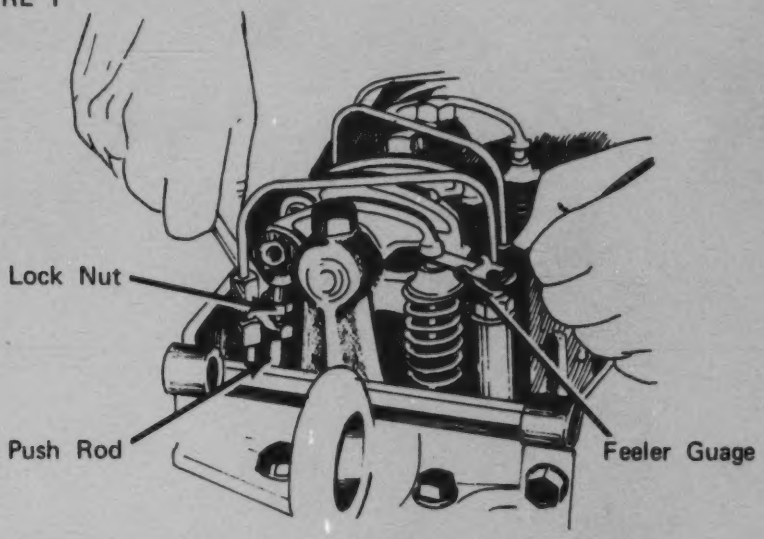
(CAUTION: When using a wrench on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation as the bolt will be loosened.)

e. Loosen the exhaust valve rocker arm pushrod locknut

JOB SHEET #3

f. Place a .013" feeler gauge between the valve stem and the valve rocker arm (Figure 1)

FIGURE 1



g. Adjust the pushrod to obtain a smooth pull on feeler gauge

h. Remove feeler gauge, hold the pushrod with a 5/16" wrench and tighten the locknut with a 1/2" wrench

i. Recheck the clearance

(NOTE: If the adjustment is correct, the .011" feeler gauge will pass freely between the valve stem and valve rocker arm but the .013" feeler gauge will not pass through. This is referred to as "go-no go" measurement.)

j. Rotate engine in the direction of travel and adjust remaining valves in same manner as above

(CAUTION: Remove device used to bar engine before starting.)

2. Adjust valves on hot engine

a. Start engine and bring to normal operating temperature (160-185°)

b. Recheck exhaust valve clearance with feeler gauge

(NOTE: Valve clearance will decrease when engine is hot, therefore, "go-no go" clearance will be .008" and .010")

JOB SHEET #3

c. Readjust the pushrod, if necessary

d. Adjust and check the remaining exhaust valves in the same manner as above

B. Time fuel injector

(NOTE: Adjust the exhaust valve clearance before timing injectors.)

1. Place governor speed control lever in idle speed position

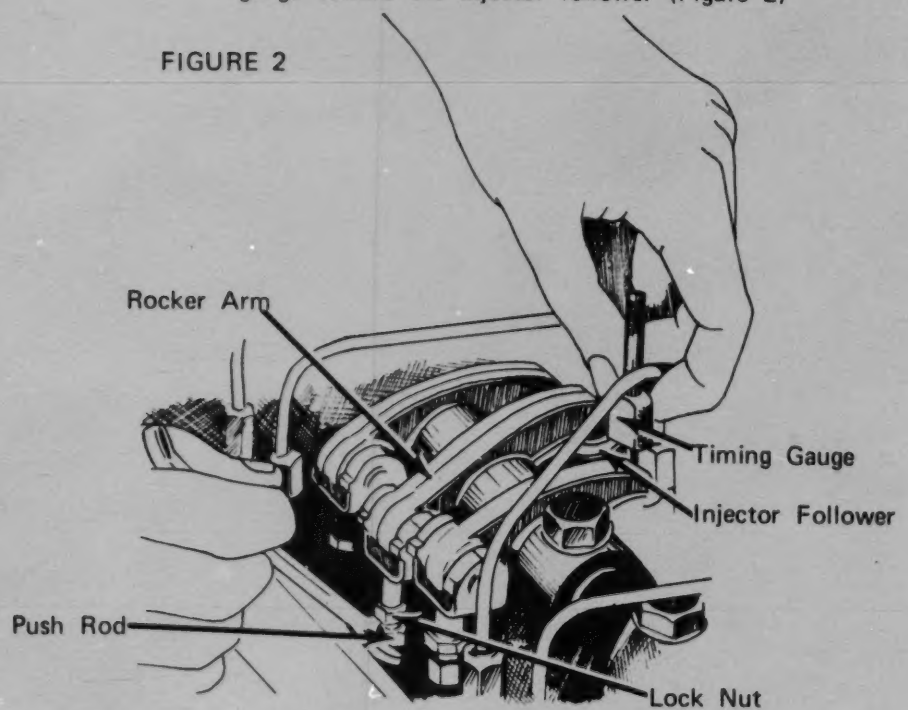
(NOTE: Secure stop lever in stop position, if used.)

2. Rotate the crankshaft, manually or with the starting motor, until the exhaust valves are fully depressed on the particular cylinder to be timed

(CAUTION: If a wrench is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft on a left-hand direction rotation or the bolt may be loosened.)

3. Place the small end of the injector timing gauge in the hole provided in the top of the injector body with the flat of the gauge toward the injector follower (Figure 2)

FIGURE 2



(NOTE: Refer to service manual for correct timing gauge and timing dimension for the injector being timed.)

JOB SHEET #3

4. Loosen the injector rocker arm pushrod locknut

5. Turn the pushrod

6. Adjust the injector rocker arm until the extended part of the gauge will just pass over the top of the injector follower

7. Hold the pushrod

8. Tighten the locknut

(NOTE: Check the adjustment and, if necessary, readjust the pushrod.)

9. Time the remaining injectors in the same manner as outlined above

10. Install the valve rocker cover, using a new gasket

C. Adjust limiting speed mechanical governor and injector rack control

(NOTE: These procedures should be completed after adjusting the exhaust valves and timing the fuel injectors.)

1. Adjust governor gap--Single weight governor

a. Start engine and bring to operating temperature

b. Stop engine

c. Loosen the lever and disconnect the fuel modulator, the power control device, the load limiting device, or the air cylinder link, if the engine is so equipped

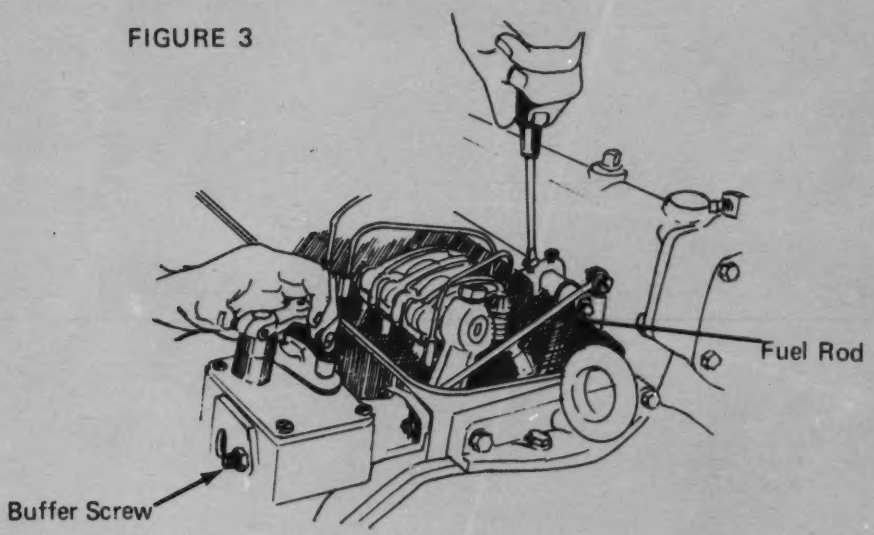
d. Remove the two attaching bolts

e. Withdraw the governor high speed spring retainer cover

JOB SHEET #3

f. Back out the buffer screw until it extends approximately 5/8" from the locknut (Figure 3)

FIGURE 3



g. Start the engine

h. Loosen the idle speed adjusting screw locknut

i. Adjust the idle screw to obtain the desired idle speed

j. Hold the screw and tighten the locknut to retain the adjustment

(NOTE: The recommended idle speed is 550 rpm for single weight governors, but may vary with special engine applications.)

k. Stop the engine

l. Remove the governor cover and lever assembly

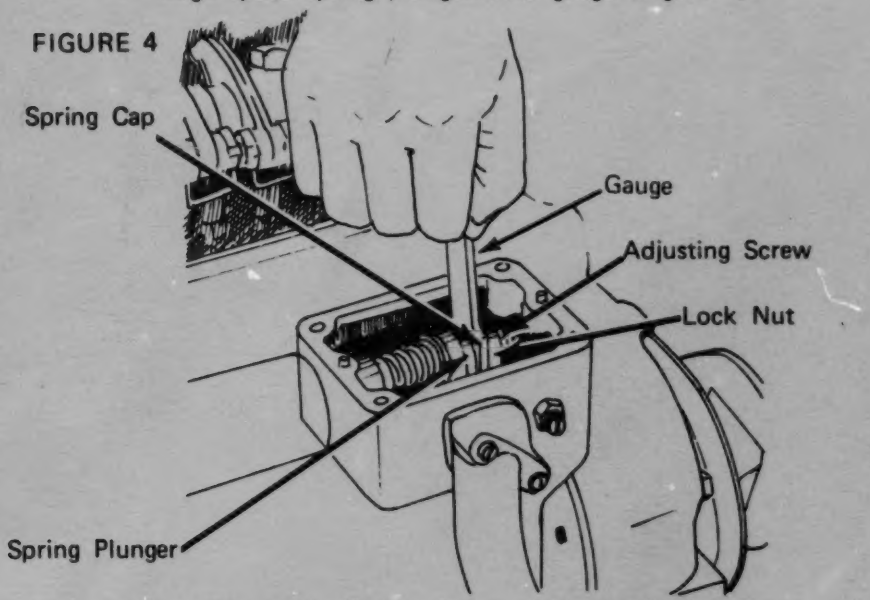
m. Clean and remove the valve rocker cover

n. Remove the fuel rod from the differential lever and the injector control tube lever

JOB SHEET #3

o. Check the gap between the low speed spring cap and the high speed spring plunger with gauge (Figure 4)

FIGURE 4



p. Loosen the locknut and turn the gap adjusting screw until a slight drag is felt on the gauge, if required

q. Hold the adjusting screw

r. Tighten the locknut

s. Recheck the gap and readjust if necessary

t. Install the fuel rod between the governor and injector control tube lever

u. Install the governor cover and lever assembly

2. Adjust governor gap on a double weight governor

a. Start engine

b. Bring to operating temperature

c. Stop engine

d. Remove the two attaching bolts

e. Withdraw the governor high speed spring retainer cover

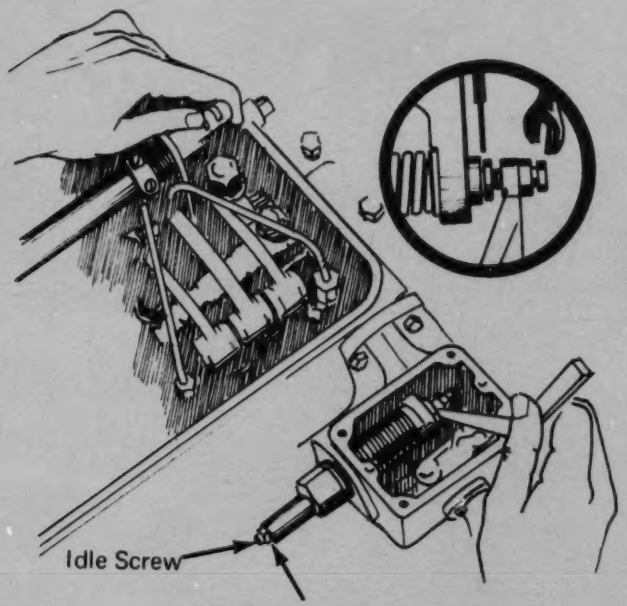
f. Back out the buffer screw until it extends approximately 5/8" from the locknut (Figure 3)

JOB SHEET #3

g. Start the engine

h. Loosen the idle speed adjusting screw locknut (Figure 5)

FIGURE 5



i. Adjust the idle screw to obtain the desired idle speed

j. Hold the screw and tighten the locknut to retain the adjustment

(NOTE: The recommended idle speed is 450 rpm for double weight governors, but may vary with special engine applications.)

k. Stop the engine

l. Remove the governor cover and lever assemble

m. Clean and remove the valve rocker cover

n. Remove the fuel rod from the differential lever and the injector control tube lever

o. Start and run the engine between 800 and 1000 rpm by manual operation of the control tube lever

(CAUTION: Do not overspeed the engine.)

p. Check the gap between the low speed spring cap and the high speed plunger with a .0015" feeler gauge (Figure 5)

(NOTE: If the gap setting is incorrect, loosen the locknut and adjust the gap adjusting screw.)

q. Hold the gap adjusting screw

r. Tighten the locknut

s. Recheck the governor gap

t. Stop the engine

u. Install the fuel rod between the differential lever and the control tube lever

v. Install the governor cover and lever assembly

D. Position injector rack control levers

1. Disconnect any linkage attached to the governor speed control lever

2. Loosen the idle speed adjusting screw locknut

3. Back out the idle speed adjusting screw until 1/2" of the threads project from the locknut when the nut is against the high speed plunger

4. Loosen all of the inner and outer injector rack control lever adjusting screws

(NOTE: On engines equipped with a yield link type fuel rod, attach a small "C" clamp at the shoulder of the rod to prevent the yield spring from compressing while adjusting the injector rack control levers.)

5. Move the governor speed control lever to the full-fuel position

6. Hold the lever in that position with light finger pressure

7. Turn the inner adjusting screw on the no. 1 injector rack control lever down until a slight movement of the control tube is observed or a step up in effort is noted.

(NOTE: This will place the no. 1 injector rack in the full-fuel position.)

8. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube

JOB SHEET #3

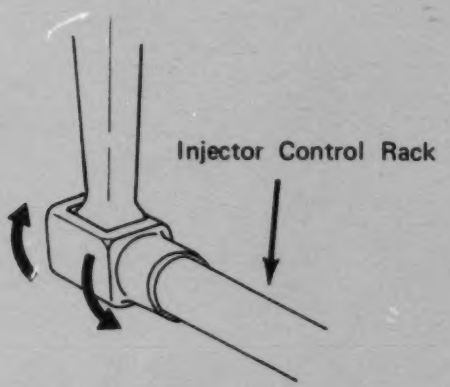
9. Alternately tighten both the inner and outer adjusting screws

(CAUTION: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws in 24-36 in-lbs.)

10. Hold the speed control lever in the full-fuel position

11. Press down on the injector rack with a screwdriver or finger tip and note "rotating" movement of the injector control rack when the speed control lever is in the full-fuel position (Figure 6)

FIGURE 6

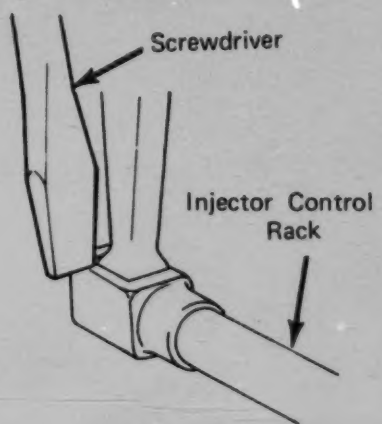


12. Hold the speed control lever in the full-fuel position

13. Use a screwdriver to press downward on the injector control rack

(NOTE: The rack should tilt downward and when the pressure of the screw drive is released, the control rack should "spring" back upward. See Figure 7.)

FIGURE 7



JOB SHEET #3

14. Check to see if rack returns to its original position

    (NOTE: If it is too loose, back off the outer adjusting screw slightly and tighten the inner adjusting screw slightly. If too tight, back off the inner adjusting screw slightly and tighten the outer adjusting screw slightly.)

15. Disconnect the fuel rod from the injector control tube

16. Hold the No. 1 injector in the full-fuel position

17. Turn down the inner adjusting screw of the No. 2 injector until the injector rack has moved into the full-fuel position and the inner adjusting screw is bottomed on the injector control tube

18. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube

19. Alternately tighten both the inner and outer adjusting screws

20. Recheck the No. 1 injector rack to be sure that it has remained snug on the ball end of the injector rack control lever while adjusting the No. 2 injector

    (NOTE: If the rack of the No. 1 injector has become loose, back off slightly on the inner adjusting screw on the No. 2 injector rack control lever and tighten the outer adjusting screw. When the settings are correct, the racks of both injectors must be snug on the ball end of their respective rack control levers.)

21. Position the remaining injector rack control levers

22. Connect the fuel rod to the injector control tube lever

23. Turn the idle speed adjusting screw in until it projects 3/16" from the locknut to permit starting the engine

24. Tighten the locknut

    (NOTE: Remove the C clamp from the fuel rod on units equipped with a yield link.)

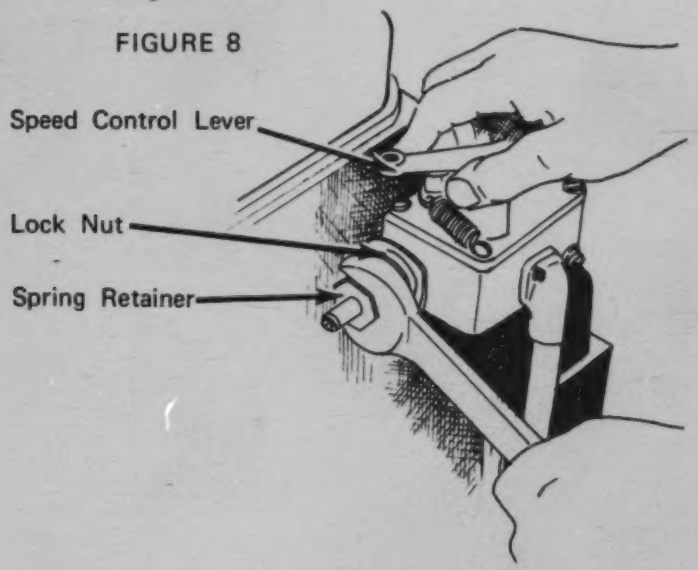
E. Adjust maximum no-load engine speed

1. Loosen the locknut

JOB SHEET #3

2. Back off the high speed spring retainer approximately five turns (Figure 8)

FIGURE 8



3. Place the speed control lever in the full-fuel position with the engine at operating temperature and no-load on the engine

4. Turn the high speed spring retainer in until the engine is operating at the recommended no-load speed

5. Hold the high speed spring retainer

6. Tighten the locknut

F. Adjust idle speed

1. Remove the spring housing to uncover the idle speed adjusting screw

2. Turn the idle speed adjusting screw until the engine is operating at approximately 15 rpm below the recommended idle speed

(NOTE: The recommended idle speed is 550 rpm for single weight governors and 450 rpm for double weight governors, but may vary with engine applications.)

3. Hold the idle screw

4. Tighten the locknut

5. Install the high speed spring retainer

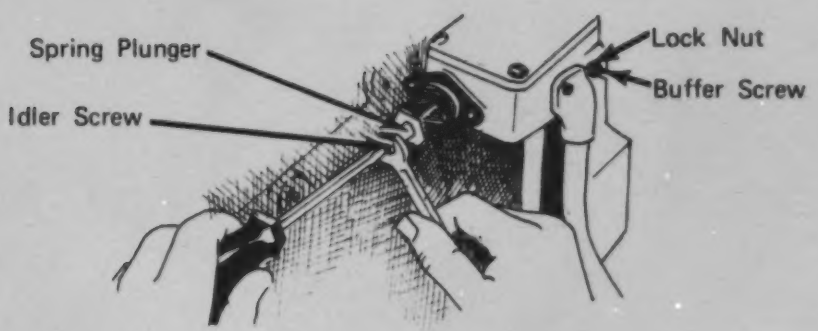
6. Retain with the two bolts

JOB SHEET #3

G. Adjust buffer screw

1. Turn the buffer screw in so that it contacts the differential lever as lightly as possible and still eliminates the engine roll (Figure 9)

FIGURE 9



(NOTE: Do not increase the engine idle speed more than 15 rpm with the buffer screw.)

2. Hold the buffer screw

3. Tighten the locknut

4. Recheck the maximum no-load speed

(NOTE: If it has increased more than 25 rpm. back off the buffer screw until the increase is less than 25 rpm)

TUNE-UP AND ADJUSTMENT
UNIT III

JOB SHEET #4--TUNE-UP A CATERPILLAR DIESEL ENGINE

I. Tools and materials

A. Basic hand tool set

B. Caterpillar special tools

C. Engine service manual

D. Shop towels

E. Compressed air source

F. Feeler gauge

G. Safety glasses

II. Procedure

A. Adjust valve lash

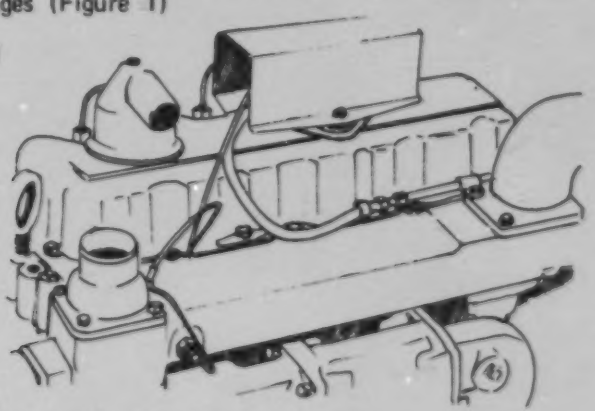
(NOTE: Engine should be run until it reaches normal operating temperature.)

1. Stop the engine

2. Clean the top of the cylinder head and the base of the valve cover

3. Remove the brackets holding the lines to the instrument panel gauges (Figure 1)

FIGURE 1



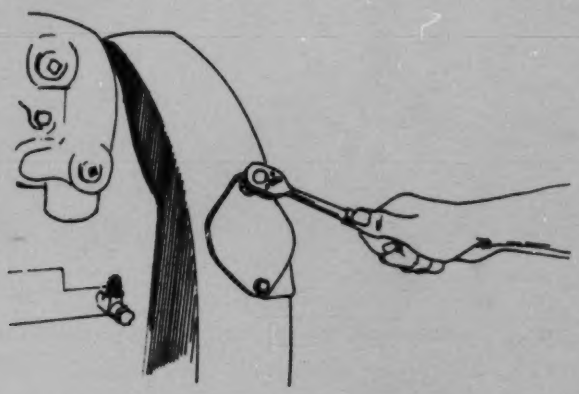
4. Remove the valve cover

(NOTE: Keep dirt from falling inside the engine block or into the valve mechanism, as the valve cover is removed.)

JOB SHEET #4

5. Remove the flywheel housing timing cover (Figure 2)

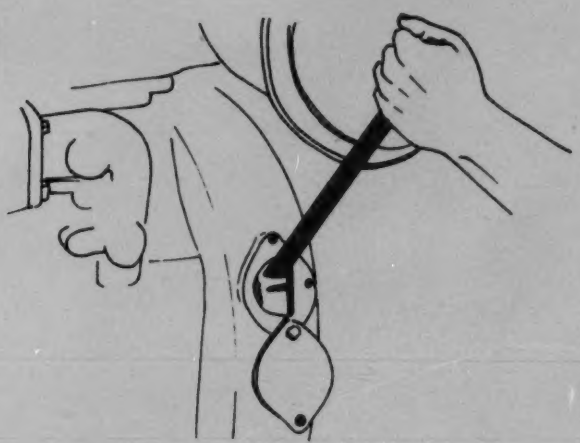
FIGURE 2



6. Bar the flywheel (Figure 3)

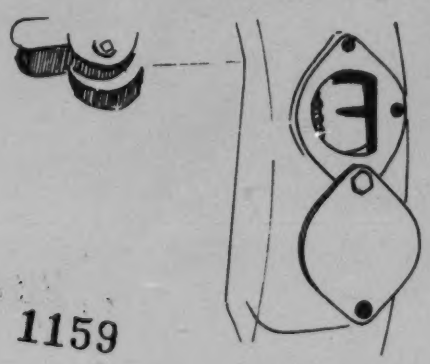
(NOTE: Refer to appropriate service manual for direction of rotation.)

FIGURE 3



7. Align the "TC-1" timing mark with the flywheel housing timing pointer (Figure 4)

FIGURE 4



JOB SHEET #4

8. Check the No. 1 cylinder rocker arms for movement and determine if the piston is on compression or exhaust stroke

   (NOTE: Compression stroke indicates both inlet and exhaust valve rocker arms can be easily moved with finger pressure. With the exhaust stroke, only inlet valve rocker arm can be moved freely with finger pressure.)

9. Check the lash of the appropriate valves as necessary

   (NOTE: Refer to appropriate service manual for procedures for valve adjustment.)

B. Set valve lash

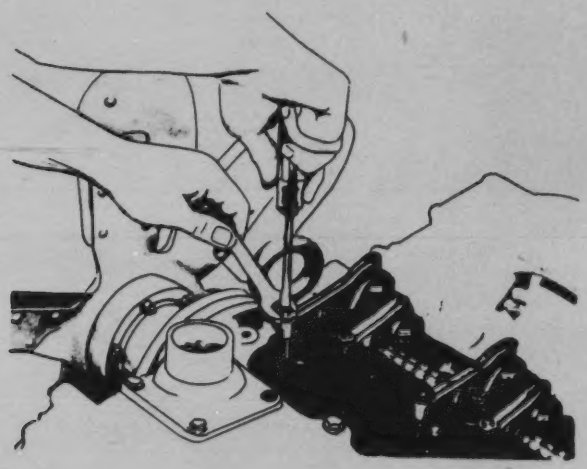
1. Loosen the locknut on the adjusting screw

2. Turn the adjusting screw to obtain the proper lash

   (NOTE: Refer to appropriate service manual for proper lash setting.)

3. Hold the adjusting screw and tighten the locknut (Figure 5)

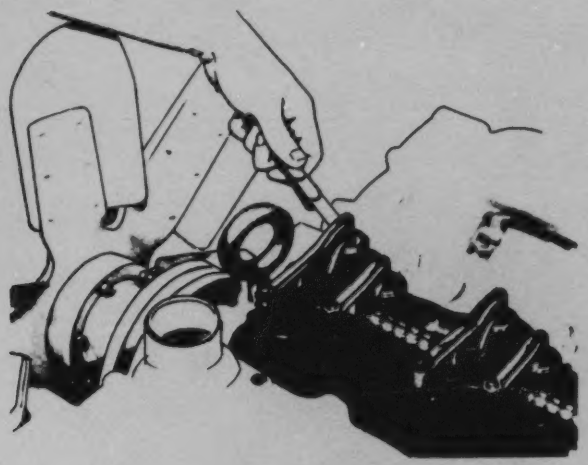
FIGURE 5



JOB SHEET #4

4. Recheck the lash (Figure 6)

FIGURE 6



C. Check valve rotation

1. Start the engine
2. Move the governor control to low idle position
3. Watch the serrations on each valve retainer

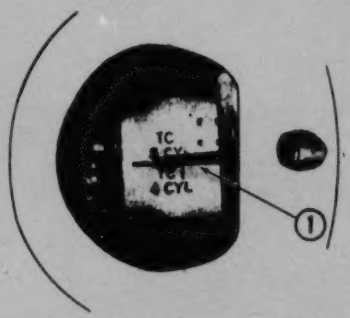
   (NOTE: Each valve retainer should turn slightly each time the valve closes.)
4. Stop the engine
5. Inspect the valve cover
6. Install a new gasket, if necessary
7. Install the valve cover
8. Install the flywheel housing timing cover

JOB SHEET #4

D. Check fuel injection pump timing

1. Locate (TC) compression position for No. 1 piston (Figure 7)

FIGURE 7



2. Time engine according to engine manufacturer's specifications

(NOTE: Use timing procedures as outlined for the timing indicator group or with a fuel pump lifter gauge.)

E. Set fuel rack, dial indicator and circuit tester

(NOTE: Always shut down the engine before adjusting rack setting.)

1. Refer to rack setting information in engine service manual to obtain correct rack setting dimension

2. Disconnect the governor control linkage, at the most convenient location

3. Remove the fuel ratio control from the rear of the governor

4. Connect dial indicator and rack positioning tool

(NOTE: Refer to appropriate service manual for installation on specific model.)

5. Zero the dial indicator

(NOTE: Consult the appropriate service manual for installation on specific models.)

(CAUTION: Before starting the engine, be sure the rack moves freely throughout its entire length of travel.)

6. Attach one end of circuit tester to the brass screw terminal on the outside of the governor housing

7. Rotate the governor control lever toward the fuel-on direction until the tester light comes on bright

   (NOTE: Depress the speed limiter to complete this step.)

8. Rotate the governor control lever toward the shutoff position until the light goes out

   (NOTE: Rotate the lever slowly.)

9. Rotate slowly the governor control lever toward the fuel-on position, until the tester light just barely comes on

   (NOTE: Rack collar is now just touching the stop bar or torque spring.)

10. Read the rack setting directly from the dial indicator

11. Adjust rack setting, if necessary

    (NOTE: Refer to appropriate service manual for adjustment of rack setting.)

F. Adjust governor

(CAUTION: Only competent personnel should attempt to adjust the low and high idle rpm.)

(NOTE: Consult the appropriate service manual for the low and high idle rpm and rack setting dimensions.)

1. Remove the cover at rear of fuel ration control

2. Engage slot in cover with cross-dowel in adjusting bolt

3. Turn the adjusting bolt in as far as possible

   (NOTE: This prevents the head of the bolt from limiting the travel of the fuel rack.)

4. Install rack positioning bracket group over the front end of the fuel rack and dial indicator in the bracket

5. Remove the plug from the bottom of the governor

6. Install plug

7. Use rod to push in the speed limiter plunger through opening

8. Tighten plug just enough to hold rod in place

JOB SHEET #4

9. Center the rack

10. Set the dial indicator on zero

11. Remove the spacer

12. Move governor control lever to full load position

    (NOTE: Complete this step with the speed limiter plunger held in.)

13. Hold the lever in the full load position while making the adjustment

14. Turn adjusting bolt out with cover until the proper dial indicator reading is obtained

    (NOTE: The proper reading is listed in the rack setting information of the appropriate service manual.)

15. Turn cover clockwise the amount necessary to align the bolt holds

16. Install cover

17. Remove the rack positioning bracket group and dial indicator

18. Install the rack cover

19. Remove plug

20. Install the standard plug

    (NOTE: Before starting the engine, make certain the governor control lever will move the governor to the shutoff position and that all parts operate freely.)

TUNE-UP AND ADJUSTMENT
UNIT IV

NAME _____

TEST

1. Define terms associated with tune up and adjustment.

   a. Tune-up--

   b. Service--

   c. Replace--

2. List five major items to include in a visual inspection checklist.

   a.

   b.

   c.

   d.

   e.

3. Demonstrate the ability to:

   a. Tune-up and service a diesel engine.

   b. Tune-up a Cummins diesel engine.

   c. Tune-up a General Motors diesel engine.

   d. Tune-up a Caterpillar diesel engine.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

TUNE-UP AND ADJUSTMENT
UNIT IV

ANSWERS TO TEST

1. a. Process of making checks and minor adjustments to improve the operation of the engine.

   b. To clean, inspect, adjust, lubricate, or repair a component or part as needed

   c. To install a new or rebuilt component or part

2. a. Oil and water leakage

   b. Electrical system

   c. Cooling system

   d. Air intake system

   e. Fuel system

3. Performance skills evaluated to the satisfaction of the instructor

ENGINE STORAGE
UNIT IV

UNIT OBJECTIVE

After completion of this unit the student should be able to define temporary and permanent engine storage and demonstrate the ability to prepare an engine for temporary storage, prepare an engine for permanent storage, and prepare a stored engine for service. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Define terms associated with engine storage.
2. Discuss the effects of climate on an engine in storage.
3. List five systems that must be protected during permanent storage.
4. Demonstrate the ability to:
   a. Prepare an engine for temporary storage.
   b. Prepare an engine for permanent storage.
   c. Prepare a stored engine for service.

ENGINE STORAGE
UNIT IV

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information and job sheets.

C. Discuss unit and specific objectives.

D. Discuss information sheets.

E. Demonstrate and discuss the procedures outlined in the job sheets.

F. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete job sheets.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Job sheets

1. Job Sheet #1--Prepare Engine for Temporary Storage

2. Job Sheet #2--Prepare Engine for Permanent Storage

3. Job Sheet #3--Prepare a Stored Engine for Service

D. Test

E. Answers to test

II. Reference--*Cummins Engine Company Shop Manual.* Columbus, Indiana: Cummins Engine Company, 1974.

ENGINE STORAGE
UNIT IV

INFORMATION SHEET

I. Terms and definitions

A. Temporary storage--Protection provided to an engine against rust and corrosion which will be out of service from four weeks to six months

B. Permanent storage--Protection provided to an engine from rust and corrosion which will be out of service over six months

II. Effects of climate on an engine in storage

A. Unpainted machine surfaces are subject to rust and corrosion

B. Rate of corrosion varies with climatic condition

III. Systems protected during permanent storage

A. Lubricating

B. Cooling

C. Fuel

D. Crankcase

E. External parts

ENGINE STORAGE
UNIT IV

JOB SHEET #1--PREPARE AN ENGINE FOR TEMPORARY STORAGE

I. Tools and materials

A. Basic hand tool set

B. Portable container of diesel fuel

C. Portable container of preservative oil, U.S. Military Specification MIL-L-644 Type P9

D. SAE #10 lubricating oil

E. Hand or power sprayer

II. Procedure

A. Start engine

B. Increase speed gradually to 1200 rpm until engine is thoroughly warm

C. Stop engine

D. Disconnect both fuel lines at fuel supply tank (the line to engine fuel filter and the injector drain line)

E. Fill two portable containers, one with regular diesel fuel and a second with preservative oil, U.S. Military Specification MIL-L-644 Type P9

F. Start the engine with the fuel line to the filter and engine, pulling fuel from the can with regular fuel

(NOTE: The injector drain line can flow into the container with regular fuel.)

G. Switch the fuel line to the container with the preservative oil after engine is running smoothly at idle

H. Operate five to ten minutes on the preservative oil

I. Stop the engine and reconnect the fuel lines to the supply tank

JOB SHEET #1

J. Drain oil sump, fuel filters, and fuel tank and reinstall drain plugs

(NOTE: New oil may be added or sump may remain empty until engine is ready for use.)

K. Tag engine with warning tag, if sump remains empty

L. Remove engine air line from air cleaner to intake manifolds

M. Turn fuel pump manual shut-off valve to "off" so engine will not start

N. Spray SAE #10 lubricating oil into intake manifold and air compressor with hand or power sprayer while bar cranking engine

O. Cover all intake manifold openings with tape to prevent entrance of dirt and moisture

P. Cover all engine openings, including coolant inlets, cylinder block, oil breather, and crankcase

Q. Drain coolant from cooling system unless it is permanent type antifreeze with rust inhibitor added

R. Store engine in a place protected from weather where air is dry and temperature uniform

S. Bar engine crankshaft two or three revolutions every three to four weeks

ENGINE STORAGE
UNIT IV

JOB SHEET #2--PREPARE AN ENGINE FOR PERMANENT STORAGE

I. Tools and materials

A. Basic hand tool set

B. Preservative oil, U.S. Military Specification MIL-L-21260, Type P-10, Grade SAE 30

C. Preservative oil, U.S. Military Specification MIL-L-64, Type P9

D. Preservative oil, U.S. Military Specification MIL-C-16173C, Type P2, Grade 1 or 2

(NOTE: Consult the manufacturer of the preservative oil or compound for the proper grade and kind of oil for preservation of the engine if there is a question regarding the correct oil.)

E. Two portable containers

F. Heavy paper

G. Tape

H. Oil spray can or brush

II. Procedure

(NOTE: Make sure engine is thoroughly clean)

A. Start engine, gradually increase speed to 1200 rpm or a fast idle, with no load, and operate until the engine is thoroughly warm

B. Stop engine and drain old oil

C. Fill crankcase to full mark on bayonet gauge or dipstick with preservative oil, U.S. Military Specification MIL-L-21260, Type P-10, Grade 2 SAE 30

D. Disconnect both fuel lines at fuel supply tank (the line to engine fuel filter and the injector drain line

E. Fill two portable containers, one with regular diesel fuel and a second with preservative oil U.S. Military Specification MIL-L-644 Type P9

JOB SHEET #2

F. Start the engine with the fuel line to the filter and engine pulling fuel from the can with regular fuel

(NOTE: The injector drain line can flow into the container with regular fuel.)

G. Switch the fuel line to the container with preservative oil after the engine is started and running smoothly at idle

H. Operate five to ten minutes on the preservative oil

I. Stop the engine and reconnect the fuel lines to the supply tank

J. Drain fuel tank, if so equipped and reinstall drain plug

K. Cover filler vent with tape

L. Drain all oil sumps of pumps, compressors, coolers, filters and crankcase

M. Replace all plugs after draining

N. Remove intake and exhaust manifolds

O. Spray all intake and exhaust ports, including air compressor intake port, with preservative oil

(NOTE: Bar or turn engine to make sure oil goes into cylinder.)

P. Replace intake and exhaust manifolds

Q. Inspect coolant in cooling system

(NOTE: If coolant is contaminated, drain and flush, fill with rust preventative compound. Drain while hot and replace plug. Use a water soluble oil with anti-rust inhibitors obtainable from an oil company. Soluble oil requires thorough flushing of cooling system before placing in service.)

R. If air starter is used, remove exhaust plate from top of starting motor and spray with preservative oil

S. Replace exhaust plate

T. Loosen V-belt tension

U. Brush or spray a film of rust preventative compound on all exposed, unpainted surfaces of engine with a rust preventative conforming to Type P-2, Grade 1 or 2, as described in U. S. Military Specification MIL-C-16173C

JOB SHEET #2

V. Remove cylinder head covers and spray preservative oil over rocker levers, valve stems, springs, guides, crossheads, and push tubes

W. Replace cover

X. Cover all engine openings, including manifold exhaust and intake port, coolant inlets to cylinder head and block, oil breather and crankcase with heavy paper and duct tape

Y. Tag engine to indicate that it has been treated with preservatives and that crankshaft should not be barred over until ready to run

(NOTE: Tag should show coolant has been removed, date of treatment, and indicate that engine is not ready to run without prior removal of protective film.)

Z. Store engine in a place protected from weather and where air is dry and temperature uniform, if possible

(NOTE: Engines in storage more than 24 months should, if practical, be thoroughly flushed out with a suitable solvent or light, hot oil and then be reprocessed with rust preventative materials. Periodically inspect engines for rust or corrosion. Take corrective action if necessary.)

ENGINE STORAGE
UNIT IV

JOB SHEET #3--PREPARE A STORED ENGINE FOR SERVICE

I. Tools and materials

A. Basic hand tool set

B. Solvent

C. Degreaser

D. Mineral oil

E. Lubricating oil

II. Procedure

A. Clean engine

1. Clean off all accumulated dirt from exterior of engine

2. Remove all paper covers, tape and wrappings

3. Remove rust preventative compound from unpainted surfaces of the engine, using a suitable solvent, cleaner, or degreaser

4. Refill crankcase with clean lubricating oil

5. Flush cooling system

B. Inspect engine in storage less than six months

1. Adjust injectors

2. Adjust valves

3. Adjust belts

4. Check head cap screws

5. Check oil filter and connections

6. Check air filter, screens, and traps

JOB SHEET #3

C. Inspect engine in storage six months or more

1. Flush entire fuel system with clean fuel oil until all preservative oil is removed

2. Remove plug from oil header and force hot, light mineral oil through the oil passages to flush away all preservative oil and gummed oil that may have accumulated

3. Bar over engine crankshaft three or four revolutions during flushing operation

(NOTE: When the combustion chambers are treated, remember that total volume of combustion space is small and any excessive preservative oil may cause hydraulic lock, seriously damaging engine if it is started before all the oil is removed.)

4. Remove all screens

5. Check to make sure they are clean before engine is started

D. Start engine

1. Pressurize the lubricating system including the turbocharger prior to starting the engine

2. Start engine as described in operation and maintenance manuals

ENGINE STORAGE
UNIT IV

NAME_____

TEST

1. Define terms associated with engine storage.

   a. Temporary storage--

   b. Permanent storage--

2. Discuss the effects of climate on an engine in storage.

3. List five systems that must be protected during permanent storage.

   a.

   b.

   c.

   d.

   e.

4. Demonstrate the ability to:

   a. Prepare an engine for temporary storage.

   b. Prepare an engine for permanent storage.

   c. Prepare a stored engine for service.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instruction when they should be completed.)

ENGINE STORAGE
UNIT IV

ANSWERS TO TEST

1. a. Temporary storage--Protection provided to an engine against rust and corrosion which will be out of service for a period of four weeks to six months

   b. Permanent storage--Protection provided to an engine against rust and corrosion which will be out of service over six months

2. Discussion should include:

   a. Unpainted machine surfaces are subject to rust and corrosion

   b. Rate of corrosion varies with climatic conditions

3. a. Lubricating

   b. Cooling

   c. Fuel

   d. Crankcase

   e. External parts

4. Performance skills evaluated to the satisfaction of the instructor

ARC WELDING
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to name kinds of arc welders, select equipment needed, and list safety precautions observed in arc welding. The student should also be able to strike an arc, run a bead, and construct a butt weld. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with arc welding to the correct definitions.
2. List safety precautions used in arc welding.
3. Name kinds of arc welders.
4. Select common equipment used in arc welding.
5. List types of electrodes.
6. Select the common sizes of electrodes used in arc welding.
7. Identify the meanings of the numbers in the electrode classification system.
8. Select purposes of electrode coating.
9. List factors to consider in selecting electrodes.
10. Describe the effects of raising and lowering the arc welding current.
11. Name two methods of striking an arc.
12. Select characteristics of proper arc length.
13. Label the parts of a drawing showing the welding process.
14. Identify kinds of welds.
15. Identify types of weld joints.
16. Name the four welding positions.

17. List reasons for poor welds.

18. Demonstrate the ability to:

    a. Start, stop, and restart a bead.

    b. Construct a pad weld.

    c. Construct a butt weld.

    d. Make a pad in the vertical up position.

    e. Make a pad in the overhead position.

ARC WELDING
UNIT I

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined on the job sheets.

G. Invite welding equipment supply companies to give class presentation.

H. Give test.

(NOTE: There are several good films and filmstrips available from the various welding supply companies. See your local distributor about films and filmstrips that are available.)

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete job sheets.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1-Welding Process

2. TM 2-Kinds of Welds

3. TM 3--Types of Weld Joints
4. TM 4--Welding Equipment
5. TM 5--AWS Classification of Electrodes
6. TM 6--Methods of Striking an Arc
7. TM 7--Welding Positions

D. Job sheets

1. Job Sheet #1--Start, Stop, and Restart a Bead
2. Job Sheet #2--Construct a Pad Weld
3. Job Sheet #3--Construct a Butt Weld
4. Job Sheet #4--Make a Pad in the Vertical Up Position
5. Job Sheet #5--Make a Pad in the Overhead Position

E. Test

F. Answers to test

II. References:

A. Jones, M. M. *Shopwork on the Farm.* 2d ed. New York: McGraw-Hill Book Co., Inc., 1955.

B. Phipps, Lloyd J.; McColly, H. F.; Scranton, L. L.; and Cook, G. C. *Farm Mechanics Text and Handbook.* Danville, Illinois: The Interstate Printers and Publishers, Inc., 1964.

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ARC WELDING
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Base metal--Metal to be cut or welded (Transparency 1)

B. Arc--Flow of current across a narrow gap, usually from the tip of the electrode to the base metal (Transparency 1)

C. Fusion process--Process of heating metal to a molten state and allowing it to cool

(NOTE: The heat is produced by the electric arc in arc welding.)

D. Arc welding--Joining together of two or more pieces of metal by the fusion process

(NOTE: This is sometimes referred to as *shielded metal arc welding* or *SMAW*.)

E. Crater--Depression at the termination of a weld (Transparency 1)

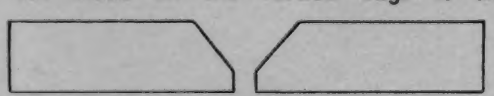
F. Pass--Single progression of a welding operation along the length of a joint or weld deposit

G. Electrode--Metal rod which conducts a current from the electrode holder to the base metal (Transparency 1)

(NOTE: The metal rod melts and deposits the metal in a bead.)

H. Bead weld--Weld made by one pass of an electrode (Transparency 2)

I. Bevel--Angular cut made on the vertical edge to allow better weld penetration



J. Butt joint--Weld between two metal joints on the same plane (Transparency 3)

K. Tack weld--Weld made to hold parts in proper alignment until the final welds are made

(NOTE: This type of welding is for assembly purposes only.)

L. Puddle--That portion of a weld that is molten at the place the heat is supplied (Transparency 1)

M. AWS--American Welding Society

INFORMATION SHEET

II. Safety precautions in arc welding

A. Do not look at the arc with the naked eye

B. Wear a head or face shield that is in good condition

C. Wear suitable clothing to protect all parts of the body

Examples: Long-sleeved shirt, leather gloves, turned-down cuffs, high top shoes or boots, buttoned-down collar

D. Do not strike an arc or weld until you are sure those in the vicinity have protective equipment or will look the other direction

(NOTE: Shout "Cover" before striking the arc.)

E. Do not weld around combustible or flammable materials

F. Use suitable tools to pick up hot metal

G. Do not weld in confined places without proper ventilation

H. Open main switch or disconnect plug when checking a welder

I. Do not leave electrode holder on welding table or in direct contact with grounded metal

J. Do not use worn or frayed cables

K. Stand on dry footing when welding

L. Keep areas around welder clean

M. Keep tools and metals in proper location

III. Kinds of arc welders

A. AC or alternating current

B. DC or direct current

C. Motor generator

(NOTE: This generator produces only DC current.)

D. Engine generator

(NOTE: The engine generator can be designed to produce AC, DC, or both types of current.)

INFORMATION SHEET

E. AC/DC transformer-rectifier

(NOTE: This welder, which is supplied by an AC power source, can be switched to produce either AC or DC welding current.)

IV. Common welding equipment (Transparency 4)

A. Welding machine

B. Electrode holder with lead

C. Ground clamp with lead

D. Shield or helmet

E. Gloves

F. Chipping hammer

G. Safety goggles or glasses

H. Wire brush

I. Electrode

V. Types of electrodes

A. Mild steel

B. High carbon steel

C. Hard surfacing

D. Low hydrogen

E. Alloy

(NOTE: Alloy electrodes are used for welding special metals such as cast iron and aluminum.)

VI. Common sizes of electrodes

(NOTE: Common sizes of electrodes range from 1/16" to 5/16".)

A. 3/32"

B. 1/8"

C. 5/32"

D. 3/16"

INFORMATION SHEET

VII. Meanings of numbers in the electrode classification system (Transparency 5)

A. E--Stands for electric arc welding

B. First two digits--Indicate tensile strength deposited in thousand pounds per square inch

C. Third digit--Indicates welding position

1. "1" indicates all positions
2. "2" indicates flat and horizontal only
3. "3" indicates flat only

D. Fourth or last digit--Represents special characteristics and usability of the electrode

Example:

Last-Digit Characteristics				
Last Digit	Power Supply	Arc Action	Type of Flux	Penetration Characteristics
0	10, DC+; 20, AC; or DC	Digging	10, organic; 20, mineral	10, deep 20, medium
1	AC or DC+	Digging	Organic	Deep
2	AC or DC	Medium	Ductile	Medium
3	AC or DC	Soft	Ductile	Light
4	AC or DC	Soft	Ductile	Light
5	DC+	Medium	Low hydrogen	Medium
6	AC or DC+	Medium	Low hydrogen	Medium
7	AC or DC	Soft	Mineral	Medium
8	AC or DC+	Medium	Low hydrogen	Medium

(Reprinted by permission from T. B. Jefferson, The Welding Encyclopedia, p. E-4, Monticello Books, Morton Grove, Illinois, 1968.)

VIII. Purposes of electrode coating

A. Stabilize the arc

B. Shield molten puddle from air

C. Float impurities out of puddle

D. Form slag and slow cooling

E. Increase speed

F. Improve quality of weld

INFORMATION SHEET

IX. Factors to consider in selecting electrodes

A. Base metal strength properties

B. Base metal composition

C. Welding position

D. Welding current

E. Joint design and fit-up

F. Thickness and shape of base metal

G. Production efficiency and job conditions

X. Effects of raising and lowering arc welding current

A. Raising the current produces more heat

B. Lowering the current produces less heat

XI. Methods of striking an arc (Transparency 6)

A. Scratching

(NOTE: This method is similar to striking a match.)

B. Tapping

XII. Characteristics of proper arc length

A. End of electrode is the same distance from the base metal as diameter of electrode

Example: For a 1/8" electrode the arc length should be 1/8"

B. Correct arc length makes a steady hum of the welder and a "frying" sound at the arc

XIII. Parts of the welding process (Transparency 1)

A. Electrode

B. Wire core

C. Coating (flux)

D. Arc

INFORMATION SHEET

E. Gaseous shield

F. Weld

G. Slag

H. Heat lines

I. Base metal

J. Penetration

K. Crater

L. 15° - 30° angle of electrode

M. Direction of travel

XIV. Kinds of welds (Transparency 2)

A. Fillet

B. Groove

C. Bead

XV. Types of weld joints (Transparency 3)

A. Edge

B. Butt

C. Corner

D. T

E. Lap

XVI. Welding positions (Transparency 7)

A. Flat

B. Horizontal

C. Vertical

(NOTE: The bead may be started either from the top or the bottom depending on the characteristics of the metal.)

D. Overhead

INFORMATION SHEET

XVII. Reasons for poor welds

A. Machine adjustment too hot or too cool

B. Electrode size too large or too small

C. Improper movement of electrode

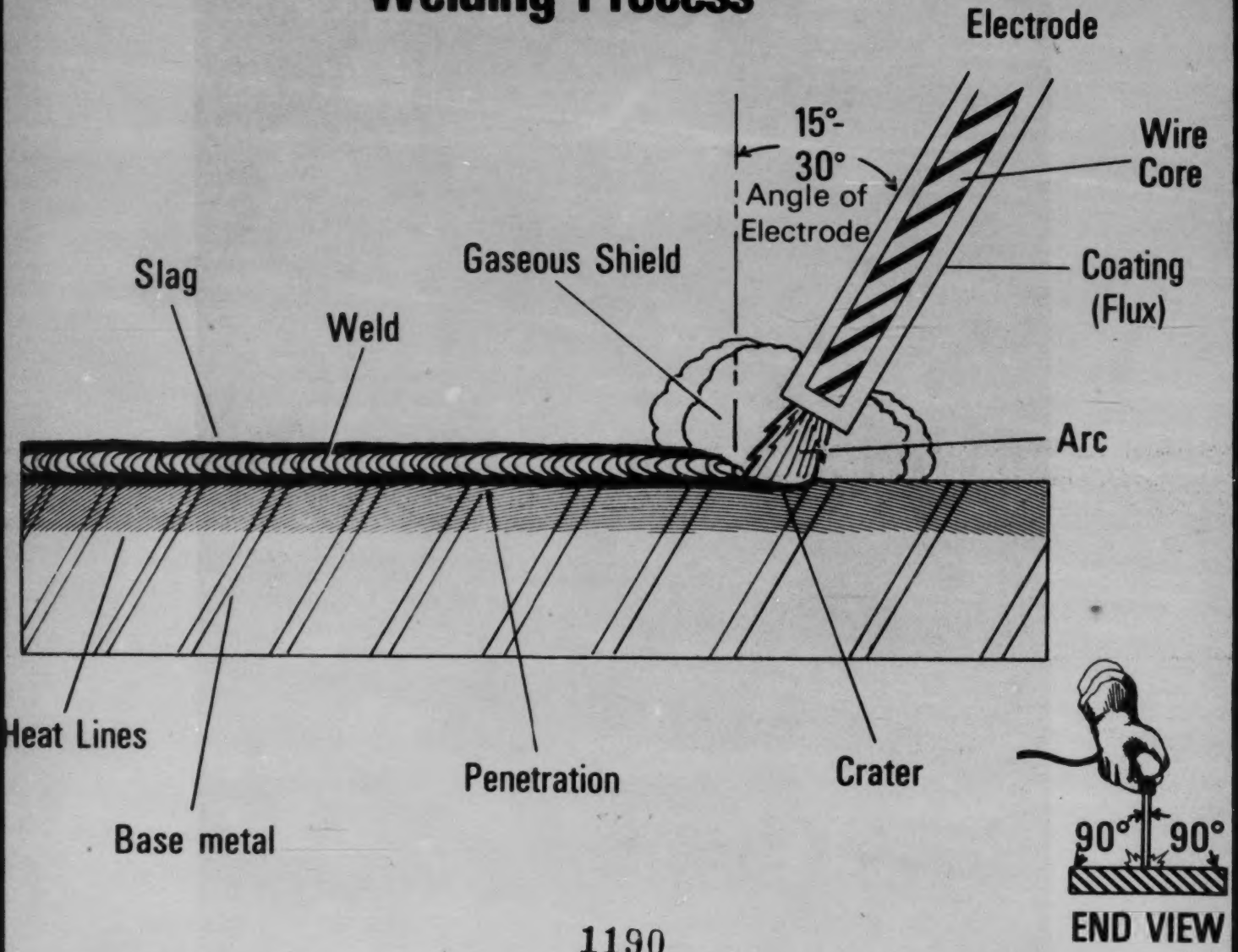
D. Improper angle of electrode

E. Improper base metal preparation

(NOTE: Base metal should be clean and free from oil and rust.)

F. Arc length too long or too short

Welding Process

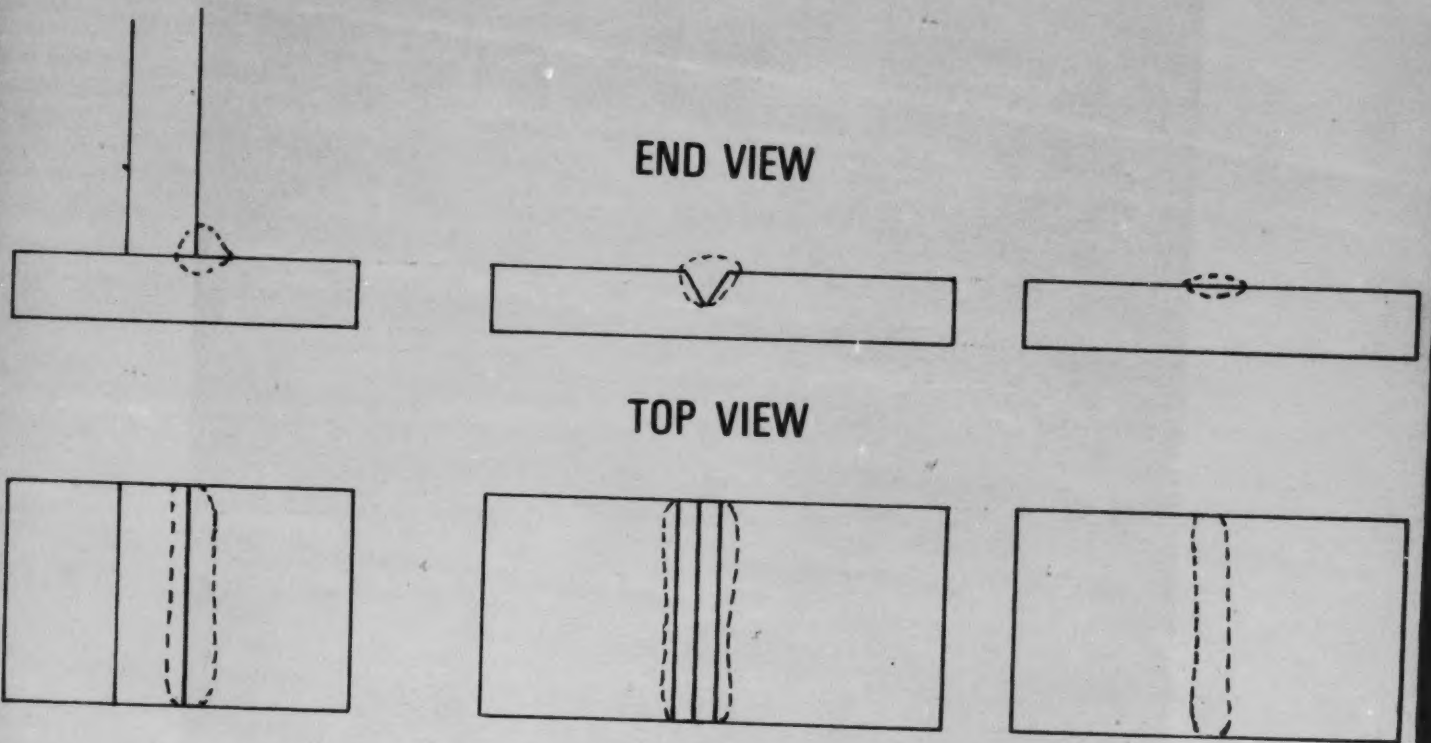


Kinds of Welds

Fillet Weld

Groove Weld

Bead Weld



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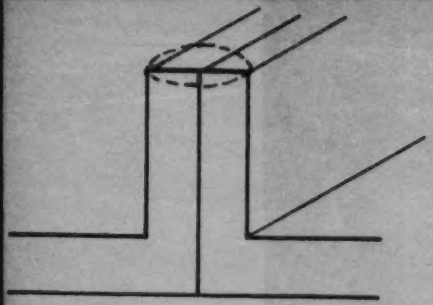
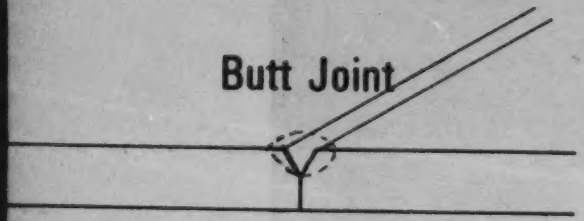
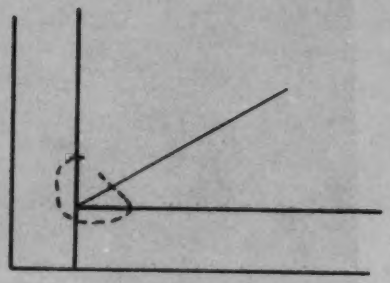
Types of Weld Joints



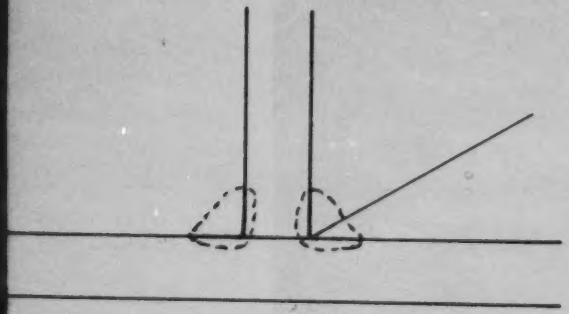
Edge Joint



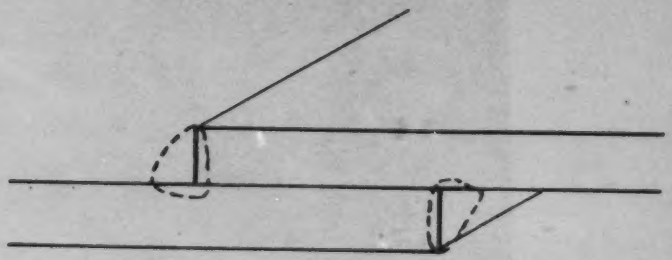
Butt Joint



Corner Joint

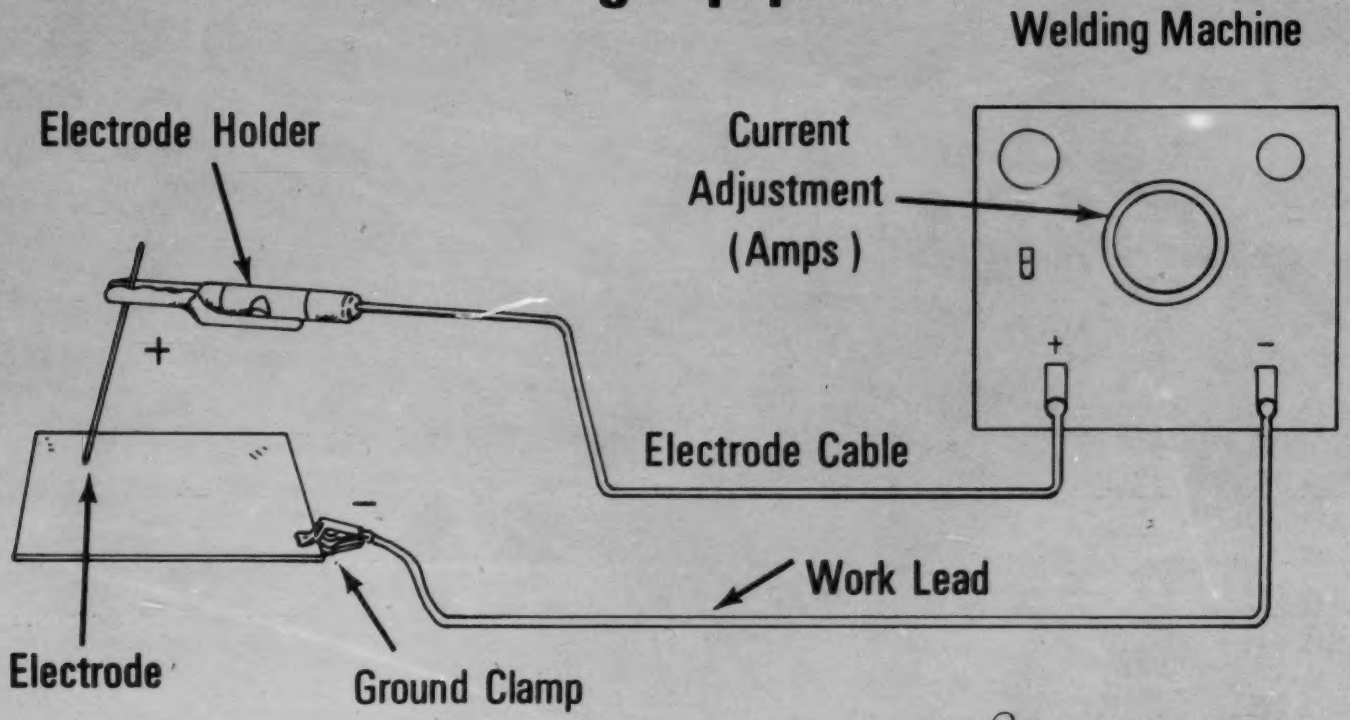


T Joint

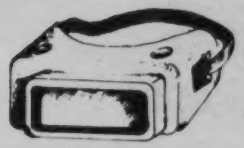


Lap Joint

Welding Equipment



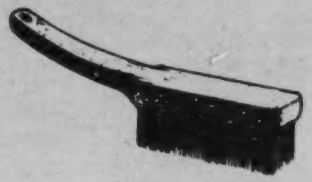
Shield or Helmet



Safety Goggles

Chipping
Hammer

Gloves



Wire Brush

TM 4

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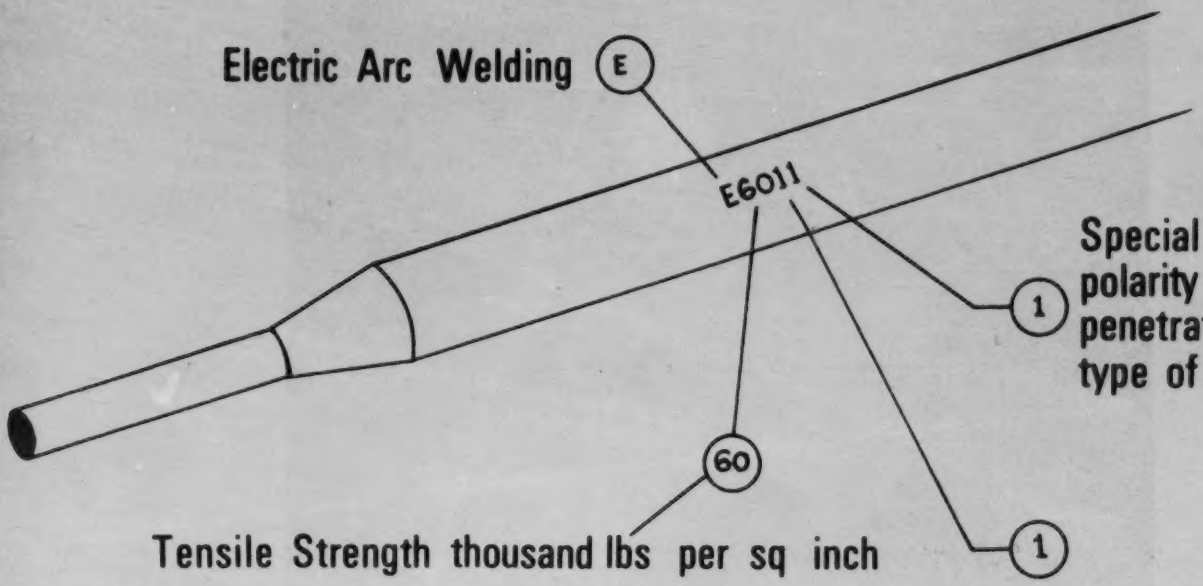
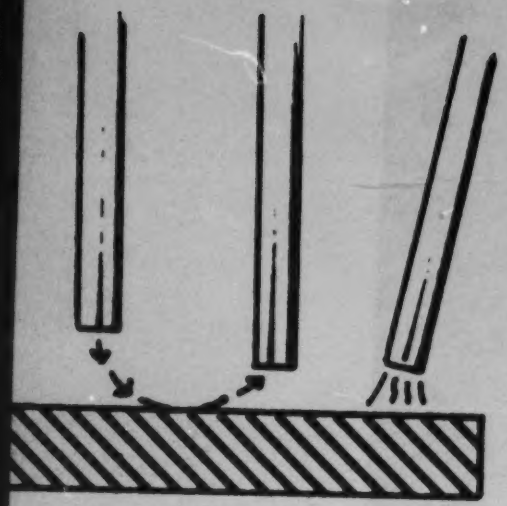
D - 19-H

AWS Classification of Electrodes

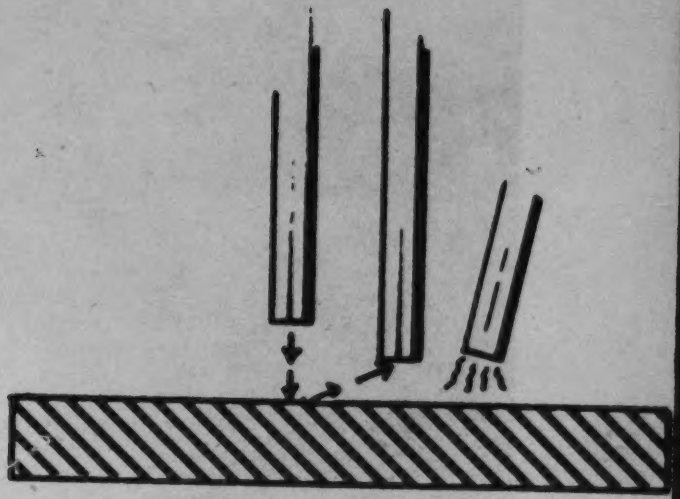


E6011 MILD STEEL ELECTRODE

Methods of Striking an Arc

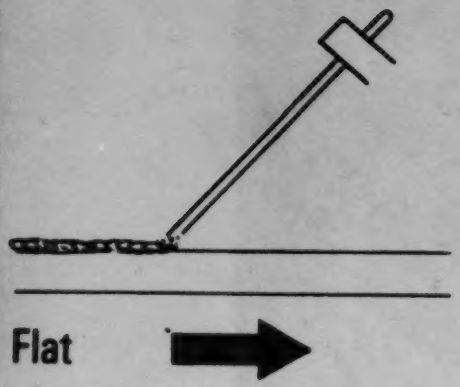


Scratching

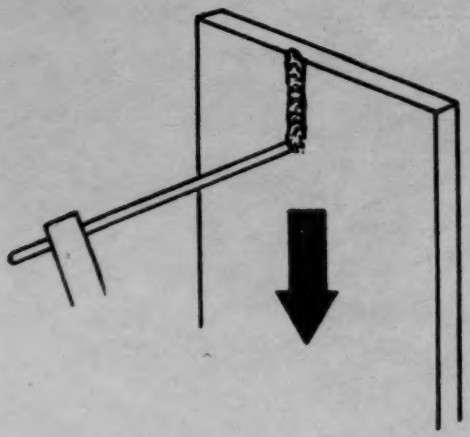


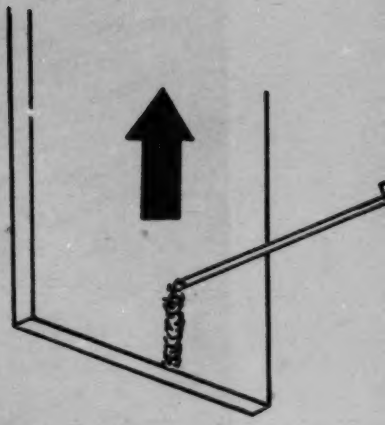
Tapping

Welding Positions

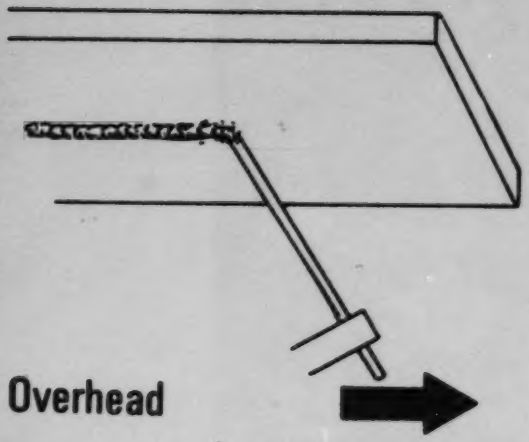


Flat

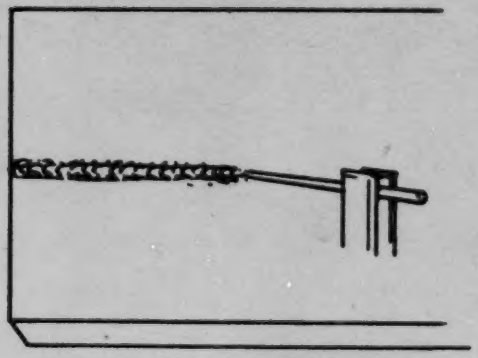




Vertical



Overhead



Horizontal

ARC WELDING
UNIT I

JOB SHEET #1--START, STOP, AND RESTART A BEAD

I. Tools and materials

A. Piece of metal 1/4" to 3/8" thick, 4" x 4"

B. Welder

C. Electrode holder with lead

D. Ground clamp with lead

E. Helmet

F. Gloves

G. Electrodes

H. Safety goggles

I. Chipping hammer

J. Wire brush

II. Procedure

A. Prepare metal for welding

(NOTE: Metal should be clean and free of oil and rust.)

B. Strike arc 1" from edge where bead is to begin (Figures 1 and 2)

FIGURE 1

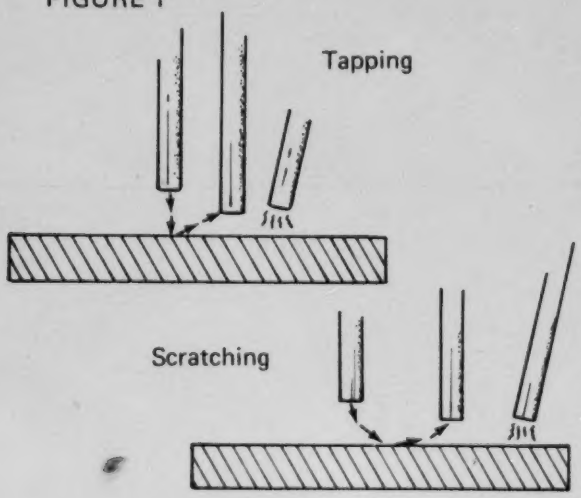
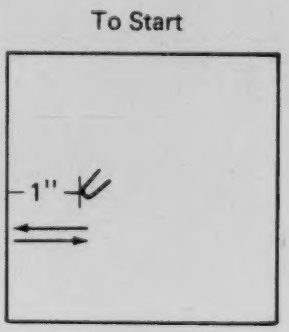


FIGURE 2



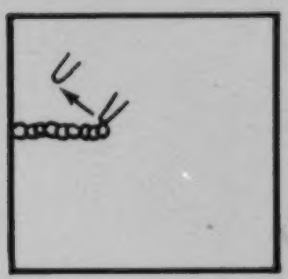
JOB SHEET #1

C. Move to edge when arc burns brightly, maintaining the correct arc length; begin forming the puddle

D. Move across metal two inches

E. Move electrode back through the puddle and lift up to stop bead (Figure 3)

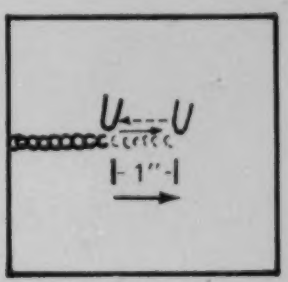
FIGURE 3



(NOTE: This will prevent cracks from forming in the puddle.)

F. Strike arc about 1" in front of crater to restart (Figure 4)

FIGURE 4



G. Move back through the crater when arc burns brightly and then resume the bead

(NOTE: This is necessary in order for beads to blend with one another without a change in continuity.)

ARC WELDING
UNIT I

JOB SHEET #2--CONSTRUCT A PAD WELD

I. Tools and materials

A. Piece of metal 1/4" to 3/8" thick, 4" x 4"

B. Welder

C. Electrode holder with lead

D. Ground clamp with lead

E. Helmet

F. Gloves

G. Electrodes

H. Safety goggles

I. Chipping hammer

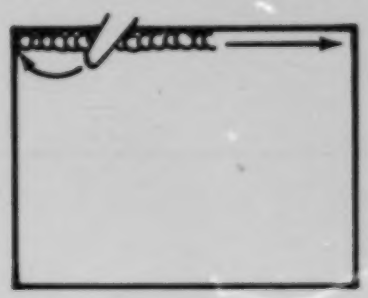
J. Wire brush

II. Procedure

A. Prepare metal for welding

B. Strike arc and move to point to begin pad (Figure 1)

FIGURE 1



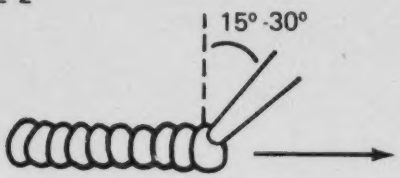
C. Lay a straight bead across the plate using a weaving motion

(NOTE: When using a E6011 electrode, it is necessary to use some type of rod manipulation in running a bead.)

JOB SHEET #2

D. Hold electrode at a 15° to 30° angle in direction of travel and lower electrode as rod burns away to maintain correct arc length (Figure 2)

FIGURE 2

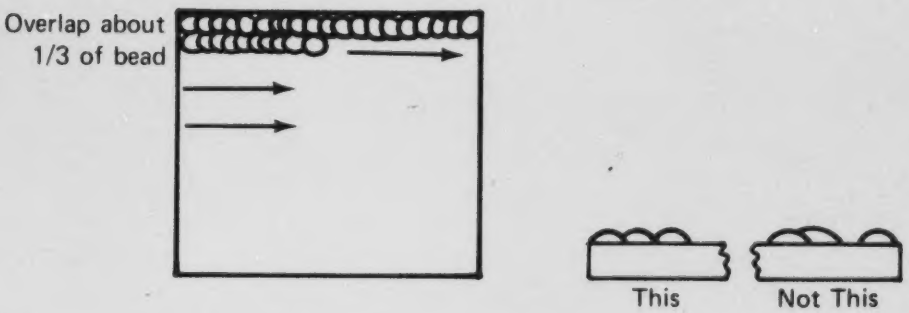


E. Move electrode steadily from right to left across pad

F. Clean the slag from each bead before starting the next one

G. Run beads until pad is full, overlapping each bead (Figure 3)

FIGURE 3



H. Let each bead cool until slag is black before chipping

I. Run additional layers until desired thickness is obtained

ARC WELDING
UNIT I

JOB SHEET #3--CONSTRUCT A BUTT WELD

I. Tools and materials

A. Pieces of metal 1/4" to 3/8" thick, 3" x 6" (2)

B. Welder

C. Electrode holder with leads

D. Ground clamp with leads

E. Helmet

F. Gloves

G. Electrodes

H. Safety goggles

I. Chipping hammer

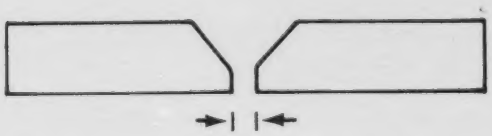
J. Wire brush

II. Procedure

A. Prepare metal to be welded (Figure 1)

(NOTE: If metal thickness is over 1/8", the edges should be beveled.)

FIGURE 1



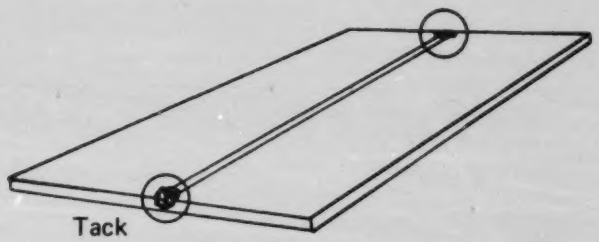
B. Place two pieces of metal parallel to each other

(NOTE: Leave a space from 1/16" to 3/32" between them. See figure 1.)

JOB SHEET #3

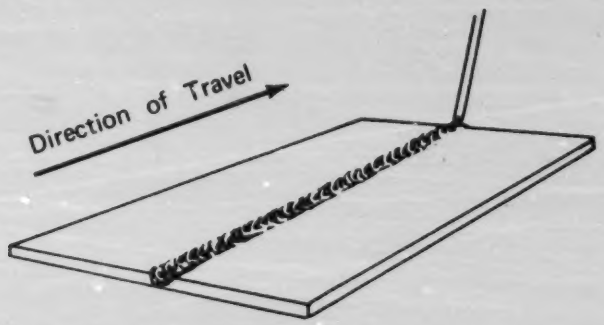
C. Tack weld pieces together at both ends (Figure 2)

FIGURE 2



D. Complete weld using a single pass (Figure 3)

FIGURE 3



E. Chip slag and brush weld

ARC WELDING
UNIT I

JOB SHEET #4--MAKE A PAD IN THE VERTICAL UP POSITION

I. Tools and materials

A. Arc welding station and required tools

B. Mild steel plates 3/8" thick, 6" by 6"

C. Electrodes E-6010 1/8" or 5/32"

1. 1/8" - 75-130 amps

2. 5/32" - 90-175 amps

D. Current Direct Current Reverse Polarity + at 1/8" electrode 75-130 amps

E. Protective clothing

F. Safety goggles

II. Procedure

A. Adjust machine to correct type and amount of current

B. Prepare and tack metal in a vertical position

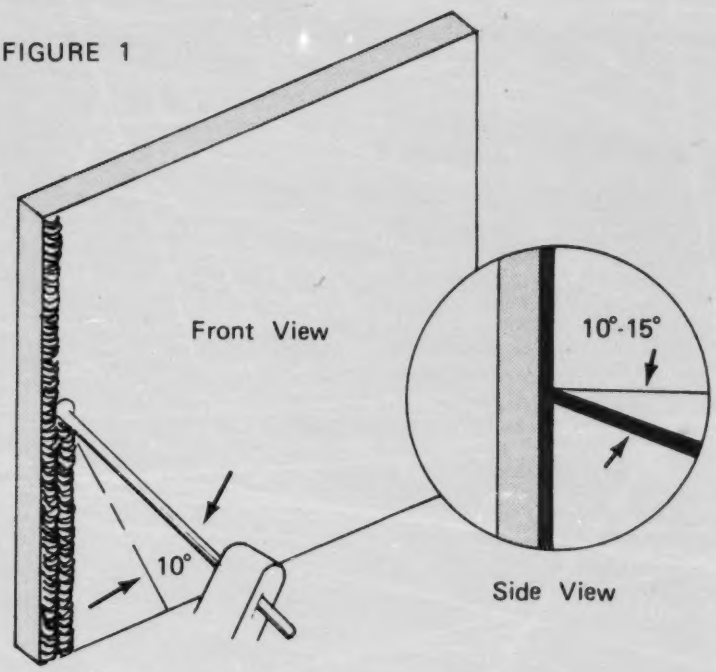
(NOTE: Vertical up welding has deeper penetration than the vertical down; this technique is usually reserved for thicker metals and requires lower amperage settings.)

C. Position electrode at 90° angle to plate and tip down from horizontal 10-15° for first bead

JOB SHEET #4

D. All other beads require a 10° side angle with each previously laid bead with the 10-15° angle down from horizontal remaining the same (Figure 1)

FIGURE 1



E. Strike an arc on the lower left hand corner of plate, hold high arc length 1 to 2 seconds and start welding upward to top of plate

(NOTE: A slight manipulation of the rod tip will be necessary.)

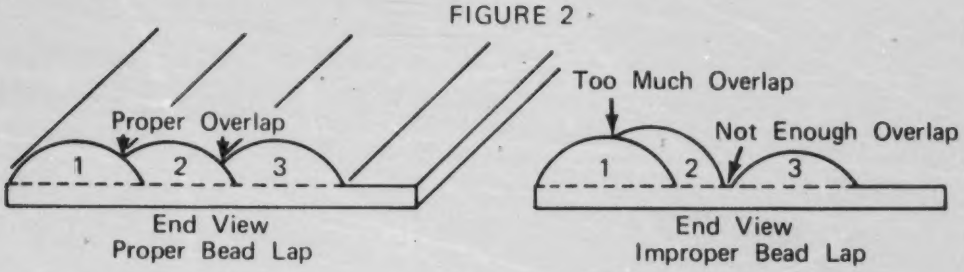
F. After laying first bead, chip and brush weld clean, and check surface for porosity and slag inclusions

(NOTE: Crater at end of each pass should be filled.)

JOB SHEET #4

G. Deposit additional beads overlapping each at least 1/3 until pad is filled (Figure 2)

FIGURE 2



H. After a complete layer of passes have been applied, clean thoroughly and turn in to instructor for evaluation

ARC WELDING
UNIT I

JOB SHEET #5--MAKE A PAD IN THE OVERHEAD POSITION

I. Tools and materials

A. Arc welding station and required tools

B. Mild steel plate 1/4" or 3/8", two pieces 6" x 6"

C. Electrode E-6010 1/8" or 5/32"

1. 1/8" - 75-130 amps

2. 5/32" - 90-175 amps

D. Protective clothing

E. Safety goggles

II. Procedure

A. Adjust welding machine to correct current and amperage setting

B. Prepare and tack metal in the overhead position

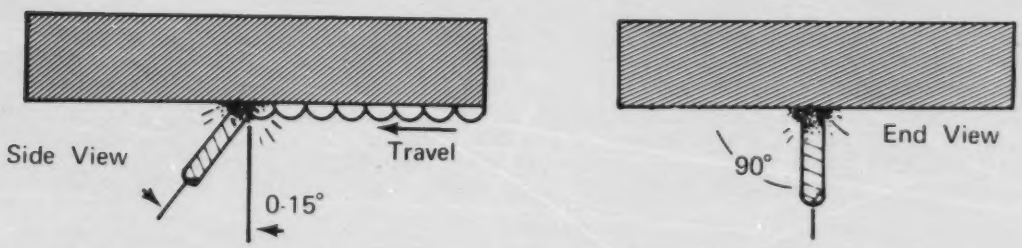
(NOTE: Metal will be in horizontal position with floor.)

C. Strike arc at edge of plate; hold a high arc for one or two seconds to heat up base metal

(CAUTION: Avoid depositing first bead too close to edge of plate.)

D. Move electrode along plate with a slight angle in the direction of travel (Figure 1)

FIGURE 1 Overhead Welding



JOB SHEET #5

(NOTE: Metal should be deposited with a very short arc. A slight whipping motion may be helpful in controlling bead shape.)

E. Start at the end of plate and progress across plate

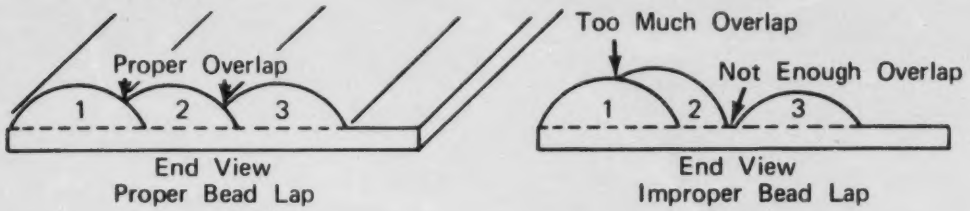
(NOTE: After completion of each bead thoroughly chip and brush the weld checking for bead appearance which will determine if current, amps, or welding technique needs to be changed.)

F. Deposit additional beads until plate is completely covered

(NOTE: Each additional bead should be overlapped about 1/3 of previous bead. Bead should have a smooth surface without noticeable "valleys" or "trapped slag.") (Figure 2)

(NOTE: Alternate travel direction for each pass.)

FIGURE 2



G. After completing the required layer of passes, clean pad and turn in for instructor's approval

ARC WELDING
UNIT I

NAME _____

TEST

1. Match the terms on the right to the correct definitions.

_____a.	Metal to be cut or welded	1.	Arc welding
_____b.	Weld made by one pass of an electrode	2.	Fusion process
_____c.	Metal rod which conducts a current from the electrode holder to the base metal	3.	Arc
		4.	Base metal
_____d.	Joining together of two or more pieces of metal by the fusion process	5.	Crater
_____e.	Depression at the termination of a weld	6.	Pass
_____f.	Angular cut made on the vertical edge to allow better weld penetration	7.	Bead weld
		8.	Bevel
_____g.	That portion of a weld that is molten at the place the heat is supplied	9.	Butt joint
_____h.	Process of heating metal to a molten state and allowing it to cool	10.	Tack weld
		11.	Electrode
_____i.	Single progression of a welding operation along the length of a joint or weld deposit	12.	Puddle
		13.	AWS
_____j.	Weld between two metal joints on the same plane		
_____k.	American Welding Society		
_____l.	Flow of current across a narrow gap, usually from the tip of the electrode to the base metal		
_____m.	Weld made to hold parts in proper alignment until the final welds are made		

2. List five safety precautions used in arc welding.

   a.

   b.

   c.

   d.

   e.

3. Name two kinds of arc welders.

   a.

   b.

4. Select common equipment used in arc welding by placing an "X" in the appropriate blanks.

   _____a. Welding machine

   _____b. Electrode

   _____c. Gloves

   _____d. Wire brush

   _____e. Cart

   _____f. Shield or helmet

   _____g. Chipping hammer

   _____h. Ball peen hammer

   _____i. Safety goggles or glasses

   _____j. Hacksaw

   _____k. Screwdriver

5. List three types of electrodes.

   a.

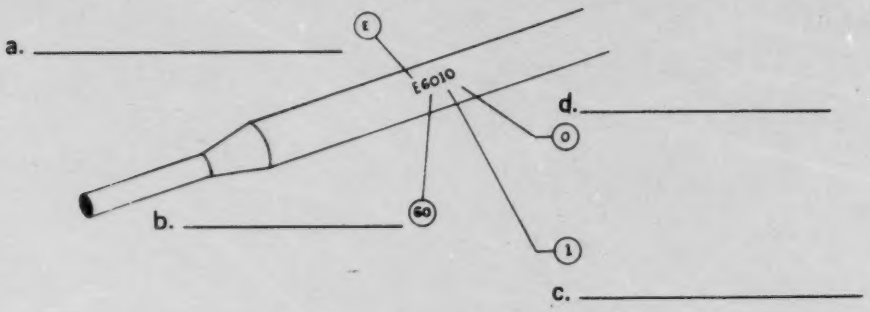
   b.

   c.

6. Select the common sizes of electrodes used in arc welding by placing an "X" in the appropriate blanks.

_____a. 1/16"
_____b. 1/8"
_____c. 3/32"
_____d. 5/16"
_____e. 5/32"
_____f. 3/16"
_____g. 3/8"
_____h. 3/64"
_____i. 3/4"
_____j. 1/2"

7. Identify the meanings of the numbers in the electrode classification system.



8. Select purposes of electrode coating by placing an "X" in the appropriate blanks.

_____a. Increase speed
_____b. Stabilize the arc
_____c. Protect the welder from shock
_____d. Shield molten puddle from air
_____e. Keep electrode from shorting out
_____f. Form slag and slow cooling
_____g. Tack metal to be welded
_____h. Float impurities out of puddle
_____i. Improve quality of weld

9. List four factors to consider in selecting electrodes.

a.

b.

c.

d.

10. Describe the effects of raising and lowering the arc welding current.

11. Name two methods of striking an arc.

a.

b.

12. Select characteristics of proper arc length by placing an "X" in the blanks.

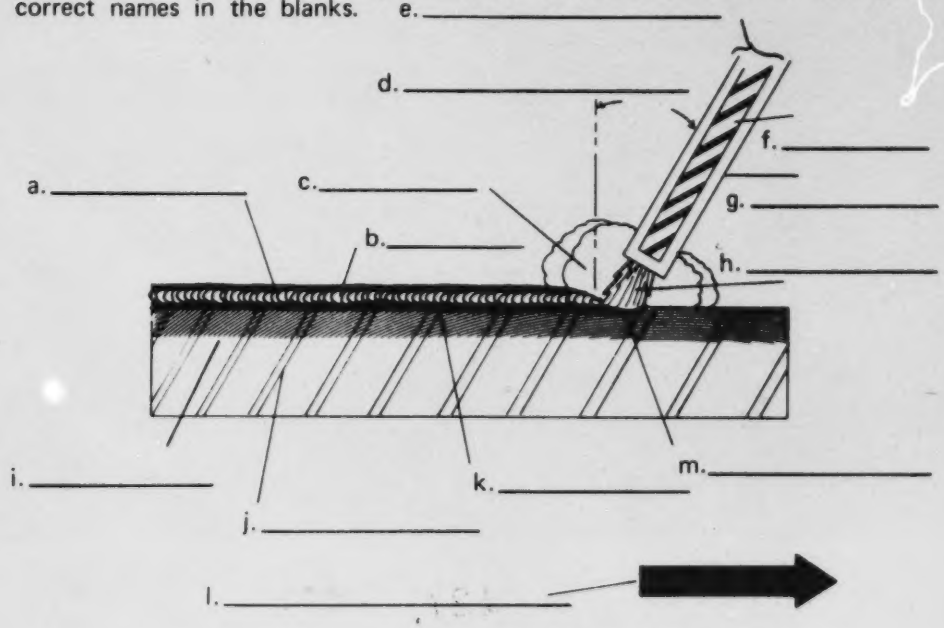
_____a. Arc length is 1/2" long

_____b. Arc length is the same as the length of the electrode

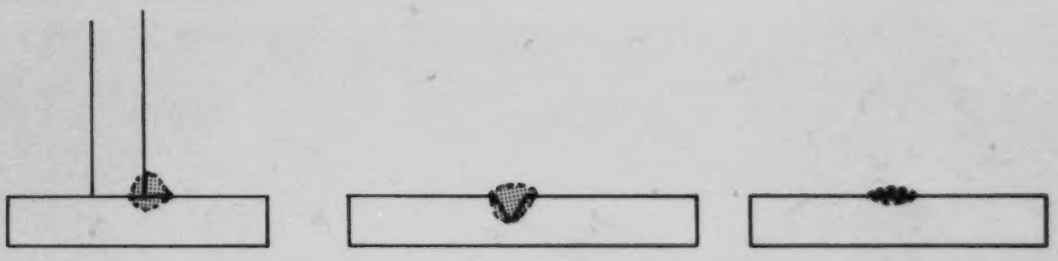
_____c. End of electrode is the same distance from the base metal as diameter of electrode

_____d. Correct arc length makes a steady hum of the welder and a "frying" sound at the arc

13. Label the parts of the welding process in the drawing below by writing the correct names in the blanks.

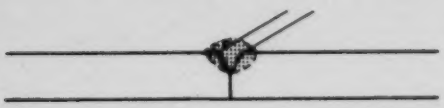


14. Identify the following welds.

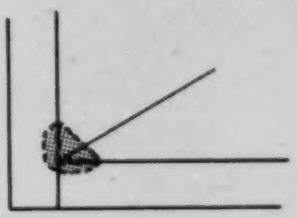


a. _____ b. _____ c. _____

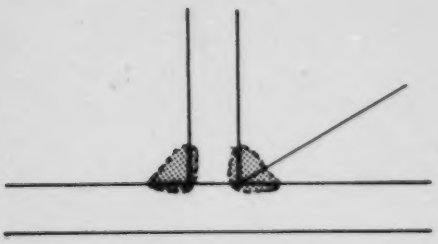
15. Identify the following weld joints.



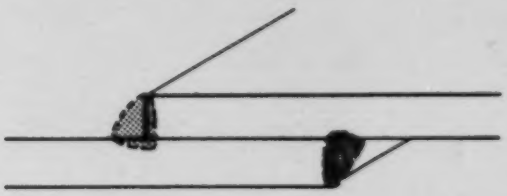
a. _____



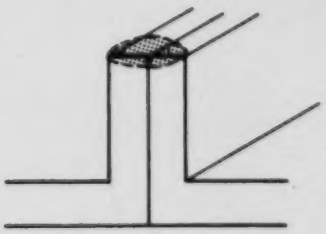
b. _____



c. _____



d. _____



e. _____

16. Name the four welding positions.

    a.

    b.

    c.

    d.

17. List four reasons for poor welds.

    a.

    b.

    c.

    d.

18. Demonstrate the ability to:

    a. Start, stop, and restart a bead.

    b. Construct a pad weld.

    c. Construct a butt weld.

    d. Make a pad in the vertical up position.

    e. Make a pad in the overhead position.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

ARC WELDING
UNIT I

ANSWERS TO TEST

1.
a.	4	h.	2
b.	7	i.	6
c.	11	j.	9
d.	1	k.	13
e.	5	l.	3
f.	8	m.	10
g.	12		

2. Any five of the following:

   a. Do not look at the arc with the naked eye

   b. Wear a head or face shield that is in good condition

   c. Wear suitable clothing to protect all parts of the body

   d. Do not strike an arc or weld until you are sure those in the vicinity have protective equipment or will look the other direction

   e. Do not weld around combustible or flammable materials

   f. Use suitable tools to pick up hot metal

   g. Do not weld in confined places without proper ventilation

   h. Open main switch or disconnect plug when checking a welder

   i. Do not leave electrode holder on welding table or in direct contact with grounded metal

   j. Do not use worn or frayed cables

   k. Stand on dry footing when welding

   l. Keep areas around welder clean

   m. Keep tools and metals in proper location

3. Any two of the following:
   a. AC or alternating current
   b. DC or direct current
   c. Motor generator
   d. Engine generator
   e. AC/DC transformer-rectifier
4. a, b, c, d, f, g, i
5. Any three of the following:
   a. Mild steel
   b. High carbon steel
   c. Hard surfacing
   d. Low hydrogen
   e. Alloy
6. b, c, e, f
7. a. E--Electric arc welding
   b. 60--Tensile strength deposited in thousand pounds per square inch
   c. 1--Welding position; all positions
   d. 0--Special characteristics and usability of electrode
8. a, b, d, f, h, i
9. Any four of the following:
   a. Base metal strength properties
   b. Base metal composition
   c. Welding position
   d. Welding current
   e. Joint design and fit-up
   f. Thickness and shape of base metal
   g. Production efficiency and job conditions

10. Description should include:
    a. Raising the current produces more heat
    b. Lowering the current produces less heat
11. a. Scratching
    b. Tapping
12. c, d
13. a. Slag
    b. Weld
    c. Gaseous shield
    d. 15° - 30° angle of electrode
    e. Electrode
    f. Wire core
    g. Coating (flux)
    h. Arc
    i. Heat lines
    j. Base metal
    k. Penetration
    l. Direction of travel
    m. Crater
14. a. Fillet
    b. Groove
    c. Bead
15. a. Butt
    b. Corner
    c. T
    d. Lap
    e. Edge

16. a. Flat

    b. Horizontal

    c. Vertical

    d. Overhead

17. Any four of the following:

    a. Machine adjustment too hot or too cool

    b. Electrode size too large or too small

    c. Improper movement of electrode

    d. Improper angle of electrode

    e. Improper base metal preparation

    f. Arc length too long or too short

18. Performance skills evaluated to the satisfaction of the instructor

OXYACETYLENE CUTTING
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to set up, light, adjust, and turn off an oxyacetylene cutting outfit following the proper order and safety precautions. The student should be able to make ninety-degree cuts on mild steel and cut round stock. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with oxyacetylene cutting to the correct definitions.
2. Identify the parts of an oxyacetylene cutting outfit.
3. Identify the parts of a torch body and cutting attachment.
4. List rules for the safe handling of oxygen and acetylene equipment.
5. Identify the types of oxyacetylene cutting flames.
6. List reasons for poor cuts.
7. Select from a list causes of a backfire.
8. Describe what happens when a backfire occurs.
9. Describe what happens when a flashback occurs.
10. List in the proper order the steps to follow in case of a flashback.
11. Demonstrate the ability to:
    a. Set up equipment for oxyacetylene cutting.
    b. Turn on, light, adjust to a neutral flame, and turn off oxyacetylene cutting equipment.
    c. Make ninety-degree cuts on mild steel and restart a cut.
    d. Cut round stock.

OXYACETYLENE CUTTING
UNIT II

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Secure color flame charts showing types of flames from welding supplier.

G. Obtain film from local welding supplier to show various techniques in cutting.

H. Demonstrate and discuss the procedures outlined in the job sheets.

I. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete job sheets.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Oxyacetylene Cutting Outfit
2. TM 2--Parts of a Torch Body and Cutting Attachment
3. TM 3--Types of Oxyacetylene Cutting Flames

D. Job sheets

1. Job Sheet #1--Set Up Equipment for Oxyacetylene Cutting
2. Job Sheet #2--Turn On, Light, and Adjust the Cutting Torch
3. Job Sheet #3--Make Ninety-Degree Cuts on Mild Steel and Restart a Cut
4. Job Sheet #4--Cut Round Stock

E. Test

F. Answers to test

II. References:

A. Althouse, Andrew D.; Turnquist, Carl H.; and Bowditch, William A. *Modern Welding.* Homewood, Illinois: The Goodheart-Willcox Co., 1970.

B. Phipps, Lloyd J.; McColly, H. F.; Scranton, L. L.; and Cook, G. C. *Farm Mechanics Text and Handbook.* Danville, Illinois: Interstate Printers and Publishers, Inc., 1964.

C. *Smith's Short Course for Gas Cutting, Welding, Brazing.* Minneapolis, Minnesota: Division of Tescom Corp./Education Department of Smith Welding Equipment.

D. *The Oxyacetylene Handbook: A Manual on Oxyacetylene Welding and Cutting Procedures.* New York: Linde Div./Union Carbide Corp.

OXYACETYLENE CUTTING
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Flashback--Fire inside of the torch

(CAUTION: This is a very dangerous condition.)

B. Backfire--Momentary burning back of the flame into the tip

C. Flame cutting--Process by which iron or steel is heated to a temperature where it can be rapidly oxidized by high purity oxygen flowing under pressure through a cutting torch

(NOTE: As the metal is oxidized, the preheat flame maintains the temperature necessary to keep the oxidation process going in a narrow zone across the length of the base metal.)

D. Slag box--Metal container with a layer of water or sand to catch hot slag

E. Slag--Metal which melts away during the oxyacetylene cutting process

F. Dragline--Situation in which the most distant portion of the cutting stream lags behind the stream nearest the cutting tip

G. Kerf--Area of material removed from a piece of metal by a saw or cutting torch

H. Oxide--Substance that is produced when oxygen is combined with an element

Examples: Rust, corrosion, coating, film, or scale

I. Oxidizing--Combining oxygen with another substance

Example: A metal is oxidized when the metal is cut

J. Purge--To remove any foreign material from a system or component by flushing with the gas used in that system

II. Parts of an oxyacetylene cutting outfit (Transparency 1)

A. Oxygen cylinder

B. Oxygen regulator

INFORMATION SHEET

C. Oxygen pressure regulating screw

D. Oxygen cylinder valve

E. Acetylene cylinder

F. Acetylene regulator

G. Acetylene pressure regulating screw

H. Acetylene cylinder valve

I. Safety chain

J. Cylinder truck

K. Oxygen hose

(NOTE: The color code for oxygen is green.)

L. Acetylene hose

(NOTE: The color code for acetylene is red.)

M. Oxygen fitting

(NOTE: The oxygen fitting has right-hand threads.)

N. Acetylene fitting

(NOTE: The acetylene fitting has left-hand threads with a grooved nut.)

O. Oxygen torch valve

P. Torch body

Q. Acetylene torch valve

R. Cutting attachment

S. Oxygen preheat valve

T. Oxygen cutting lever

U. Tip

V. Tip nut

INFORMATION SHEET

III. Parts of the torch body and cutting attachment (Transparency 2)

A. Cutting torch

1. Oxygen fitting
2. Acetylene fitting
3. Oxygen torch valve
4. Acetylene torch valve
5. Torch body
6. Oxygen cutting lever
7. Oxygen preheat valve
8. Tip nut
9. Tip

B. Cutting tip

(NOTE: The selection of the correct tip for the job is determined by the thickness of metal, the size of tip orifice, and the oxygen cutting pressures. See manufacturer's recommendations.)

1. Preheat orifice

(NOTE: The preheat orifice heats metal to kindling point of approximately 1600° F 755° C .)

2. Cutting orifice

(NOTE: The cutting orifice removes oxidized metal.)

IV. Rules for safe handling of oxygen and acetylene equipment

A. Secure cylinders in an upright position to prevent damage to valves or regulators

B. Purge cylinder valve before attaching regulators

C. Release adjusting screws on regulator before opening cylinder valve

D. Stand to one side of regulator while slowly opening the cylinder valve

INFORMATION SHEET

E. Do not use acetylene at pressures higher than 15 psi

(NOTE: Acetylene becomes unstable at pressures higher than 15 psi and becomes highly explosive.)

F. Purge oxygen and acetylene passages before lighting torch

G. Light acetylene gas before opening oxygen valve on torch

H. Do not use oil on regulators, torches, fittings, or any place that it may come in contact with oxygen

(NOTE: Oil or grease and oxygen have a very great attraction for one another and will unite with explosive violence.)

I. Do not use oxygen as a substitute for compressed air

J. Keep heat, flames, and sparks away from combustibles

K. Use safety goggles, gloves, and protective clothing

(NOTE: Keep gloves, hands, and clothing free from oil and grease.)

L. Test connections for leaks with soapsuds and paintbrush

M. Do not weld on containers that have been used for combustable materials

N. Avoid breathing toxic fumes when welding

Example: Galvanized metal

O. Do not leave a burning torch unattended

P. Do not cut or weld near concrete

Q. Operate torch in a well-ventilated place

R. Weld or cut at least five feet from cylinders

S. Protect hoses from hot metal, rupture, or mechanical damage

V. Types of oxyacetylene cutting flames (Transparency 3)

A. Carburizing flame

(NOTE: The flame has an excess of acetylene gas.)

INFORMATION SHEET

B. Neutral flame

(NOTE: The flame has the proper ratio of oxygen to acetylene.)

C. Oxidizing flame

(NOTE: There is an excess of oxygen.)

VI. Reasons for poor cuts

Example:

(NOTE: This is a correctly made cut in one-inch plate. The edge is square and the draglines are essentially vertical and not too pronounced.)

A. Preheat flames too small

Example:

(NOTE: The cutting speed was too slow, causing bad gouging at the bottom.)

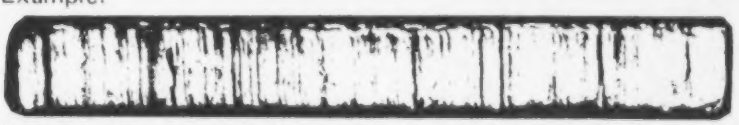
B. Preheat flames too long

Example:

(NOTE: The top surface has melted over, the cut edge is irregular, and there is an excessive amount of adhering slag.)

C. Oxygen pressure too low

Example:



(NOTE: The top edge has melted over because the cutting speed was too slow.)

INFORMATION SHEET

D. Oxygen pressure too high; nozzle size too small

Example:

(NOTE: The entire control of the cut has been lost.)

E. Cutting speed too slow

Example:

(NOTE: The irregularities of the draglines are emphasized.)

F. Cutting speed too fast

Example:

(NOTE: There is a pronounced break to the dragline and the cut edge is irregular.)

G. Blowpipe travel unsteady

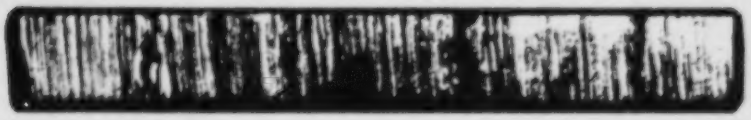
Example:

(NOTE: The cut edge is wavy and irregular.)

INFORMATION SHEET

H. Cut lost and not carefully restarted

Example:



(NOTE: Bad gouges were caused at the restarting point.)

VII. Causes of a backfire

A. Insufficient acetylene or oxygen pressure

B. Loose cutting tip

C. Dirty tip

D. Overheating of cutting tip

E. Bad "O" ring in torch body

(NOTE: The above causes should be carefully checked to avoid backfire.)

VIII. What happens when a backfire occurs

A. Flame burns momentarily back into tip

B. A loud snap or pop is emitted from the torch

C. Flame either goes out or continues to burn in normal manner

IX. What happens when a flashback occurs

A. Flame disappears inside the torch body

B. Squealing noise, smoke, and/or sparks are emitted from the torch tip

X. Steps to follow in case of a flashback

A. Close oxygen preheat valve

B. Close oxygen torch valve

C. Close acetylene torch valve

D. Release oxygen regulator screw

INFORMATION SHEET

E. Release acetylene regulator screw

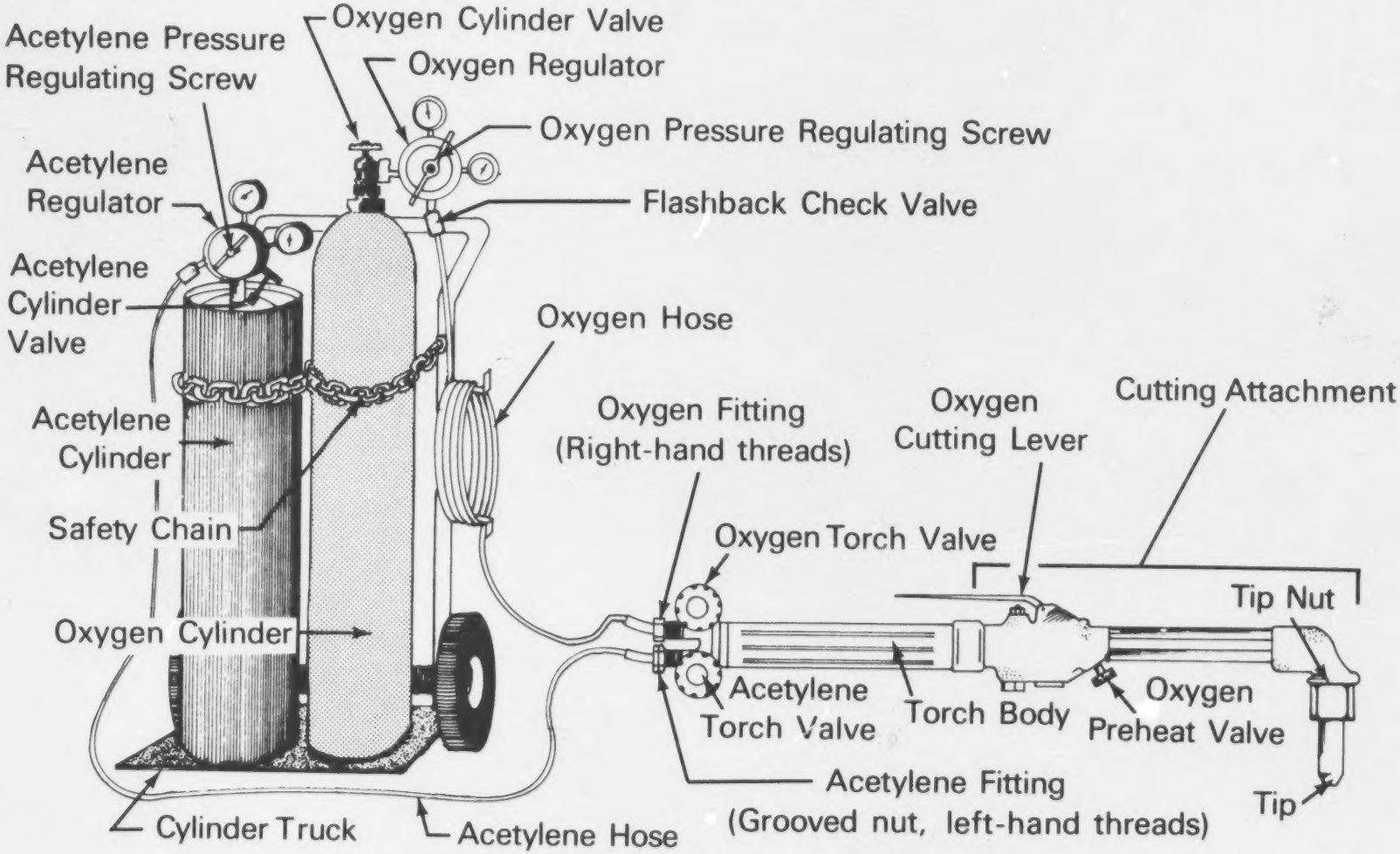
F. Examine acetylene unit

G. Reset regulator pressures

H. Light torch

(NOTE: If heavy smoke comes out of the torch tip and the torch body becomes hot, the flashback has probably traveled past the mixing chamber into the hose. In this case, shut off the oxygen cylinder valve and the acetylene cylinder valve and then notify the instructor.)

Oxyacetylene Cutting Outfit



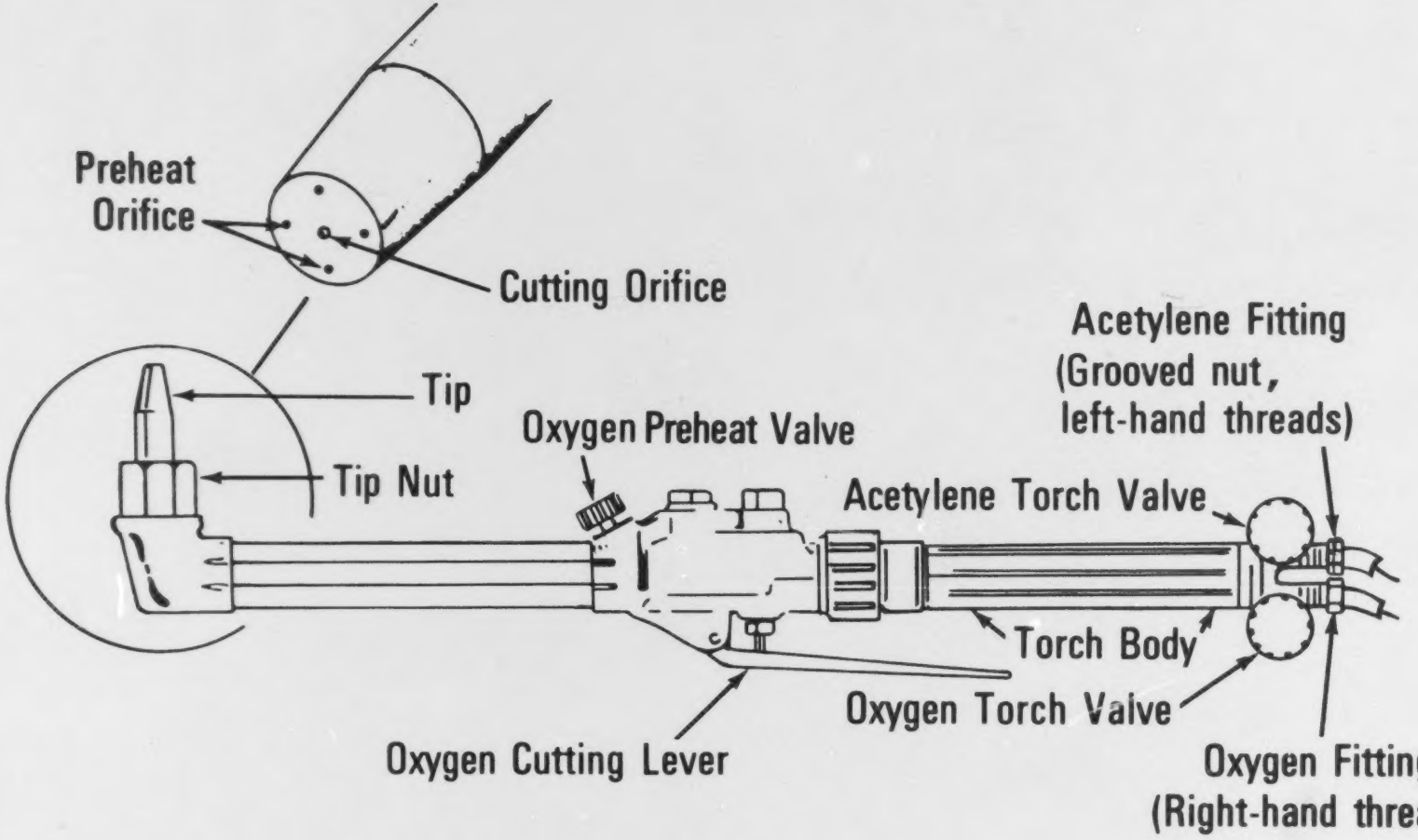
TM 1

1230

1231

D - 61-H

Parts of a Torch Body and Cutting Attachment



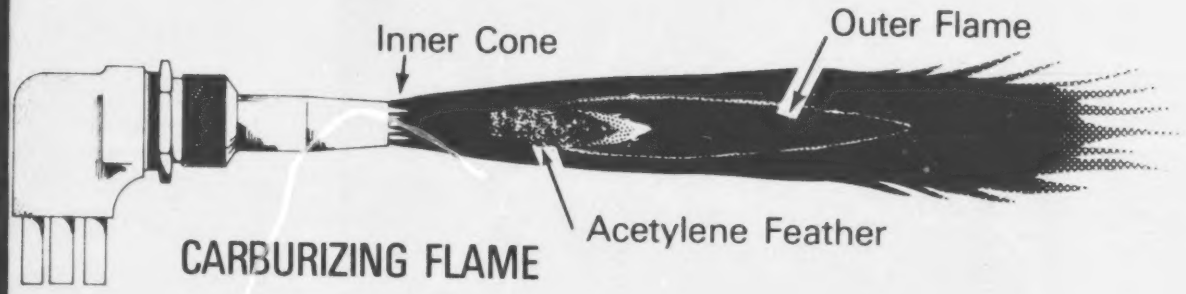
TM 2

1232

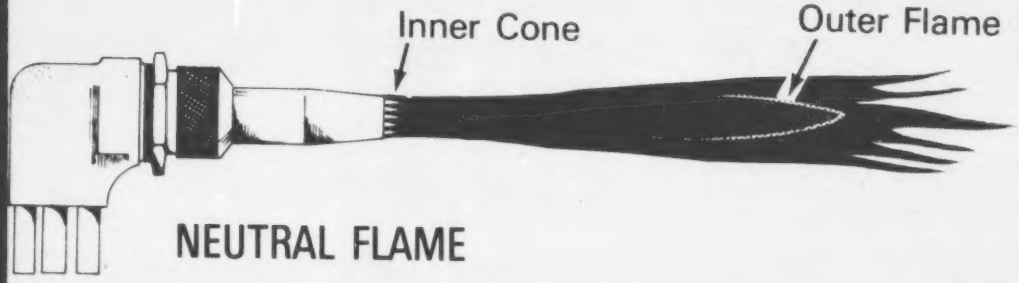
D - 63-H

1233

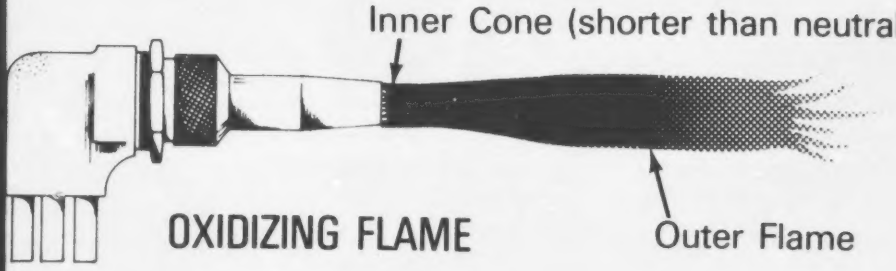
Types of Oxyacetylene Cutting Flames



CARBURIZING FLAME



NEUTRAL FLAME



OXIDIZING FLAME

OXYACETYLENE CUTTING
UNIT II

JOB SHEET #1--SET UP EQUIPMENT FOR OXYACETYLENE CUTTING

I. Tools and materials

A. Oxygen cylinder

B. Acetylene cylinder

C. Oxygen regulator

D. Acetylene regulator

E. Hoses

F. Wrench

G. Cylinder holder

H. Water container

I. Liquid detergent

J. Clean paintbrush

K. Torch body with tips

II. Procedure

A. Secure cylinders in a vertical position

B. Remove caps from cylinders

C. Crack valves of each cylinder to remove foreign material; close valves

D. Connect oxygen regulator to oxygen cylinder

(CAUTION: Do not use oil on any connections on the oxyacetylene system.)

1. Turn adjusting screw on regulator counterclockwise until tension on spring is released

2. Turn cylinder valve wide open slowly

JOB SHEET #1

E. Connect acetylene regulator to acetylene cylinder

1. Turn adjusting screw on regulator counterclockwise until tension on spring is released

2. Open cylinder valve 1/2 to 3/4 of a turn

(NOTE: Never open cylinder valve more than 1 1/2 turns.)

F. Connect acetylene hose to acetylene regulator; purge hose

G. Connect oxygen hose to oxygen regulator; purge hose

H. Connect torch body to oxygen and acetylene hoses

I. Close both valves on torch body

J. Attach cutting attachment to torch body

(NOTE: The tip size is determined by the thickness of metal to be cut and the manufacturer's recommendations.)

K. Close oxygen preheat valve on cutting attachment

L. Turn adjusting screw on oxygen regulator clockwise until working pressure is reached

M. Turn adjusting screw on acetylene regulator clockwise until correct working pressure is reached

N. Test all connections for leaks with liquid detergent suds and water

(NOTE: Apply soap suds with a clean paintbrush.)

OXYACETYLENE CUTTING
UNIT II

JOB SHEET #2--TURN ON, LIGHT, AND ADJUST THE CUTTING TORCH

I. Tools and materials

A. Oxyacetylene cutting outfit

B. Wrench

C. Gloves

D. Safety goggles

E. Coveralls or protective clothing

II. Procedure for turning on, lighting, and adjusting the cutting torch to a neutral flame

A. Check all cylinder, regulator, and torch valves to make sure they are closed

B. Open acetylene cylinder valve 1/2 to 3/4 of a turn

(NOTE: Never open cylinder valve more than 1 1/2 turns.)

C. Open acetylene valve on torch one turn

D. Turn adjusting screw on acetylene regulator clockwise until desired pressure is reached

(NOTE: Oxygen and acetylene pressures and size of tip depend upon the thickness of metal to be cut. Use pressures and tip size recommended by manufacturer.)

E. Close acetylene valve on torch

F. Open oxygen cylinder valve all the way

G. Open oxygen torch valve all the way

H. Open oxygen preheat valve on cutting attachment one turn

I. Turn adjusting screw on oxygen regulator clockwise until desired pressure is reached

J. Close oxygen preheat valve on cutting attachment

K. Open acetylene valve on torch 1/4 turn

JOB SHEET #2

L. Light the torch with flint lighter and adjust until smoke on flame clears

M. Open oxygen preheat valve slowly and adjust to a neutral flame

N. Depress the oxygen cutting lever and check to see that a neutral flame is present

(NOTE: If necessary, adjust the oxygen preheat valve with the oxygen cutting lever depressed until a neutral flame is secured.)

III. Procedure for turning off the flame and oxyacetylene unit

A. Close acetylene valve on torch

B. Close oxygen preheat valve

C. Close acetylene cylinder valve

D. Close oxygen cylinder valve

E. Open acetylene valve on torch

(NOTE: When gauges reach "0", close torch valve and release adjusting screw on acetylene regulator by turning counterclockwise.)

F. Open oxygen preheat valve on torch

(NOTE: When gauges reach "0", close oxygen preheat valve and release adjusting screw on oxygen regulator by turning counterclockwise.)

G. Close oxygen valve on torch

H. Place torch and hose on hanger or brackets provided

OXYACETYLENE CUTTING
UNIT II

JOB SHEET #3-MAKE NINETY-DEGREE CUTS ON MILD STEEL AND RESTART A CUT

I. Tools and materials

- A. Cutting outfit
- B. Mild steel plate 1/4" to 1/2" thick, 4" wide or wider, 8" long or longer
- C. Soapstone with a sharp point or edge
- D. Straightedge
- E. Gloves
- F. Safety goggles
- G. Pliers
- H. Coveralls
- I. Flint lighter
- J. Welding or cutting table
- K. Slag box
- L. Can of water
- M. Cutting tip

II. Procedure

- A. Mark four parallel lines 2" apart on plate to be cut
- B. Adjust oxygen regulator
- C. Adjust acetylene regulator
- D. Place plate over slag box
- E. Light torch
- F. Adjust to neutral flame
- G. Assume comfortable position

JOB SHEET #3

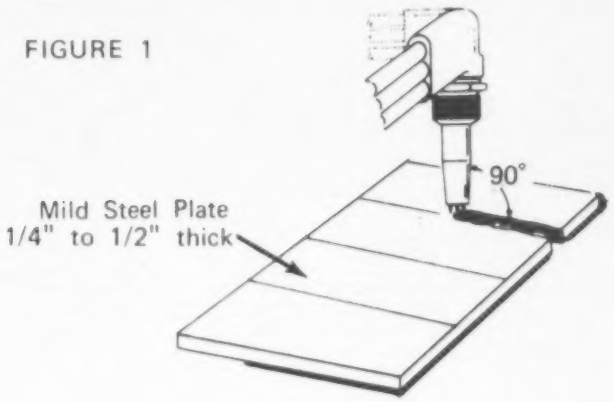
H. Place hoses behind you

I. Maneuver torch with both hands

J. Hold preheat flame with tip of inner cone 1/16" to 1/8" above top of plate at right edge until red spot appears

K. Depress the oxygen cutting lever and move from right to left across the plate (Figure 1)

FIGURE 1



L. Hold the tip at right angle to work while cutting with inner cone being 1/16" to 1/8" above work

M. Make 90° cuts until you have developed the proper procedure

N. Cool metal by placing in can of water with the aid of pliers

O. Show samples to instructor for approval and grading

III. Procedure for restarting a cut

A. Release the oxygen cutting lever

B. Preheat edge only where cutting action was stopped

C. Depress oxygen cutting lever slowly and continue cut

OXYACETYLENE CUTTING
UNIT II

JOB SHEET #4--CUT ROUND STOCK

I. Tools and materials

- A. Cutting outfit
- B. Pieces of reinforcing bar, 1/2", 5/8", 3/4", or 1"
- C. Soapstone with sharp point or edge
- D. Tape measure
- E. Gloves
- F. Safety goggles
- G. Pliers
- H. Coveralls
- I. Flint lighter
- J. Welding or cutting table
- K. Slag box
- L. Can of water
- M. Cutting tip

II. Procedure

- A. Mark reinforcing bar to desired length
- B. Adjust oxygen and acetylene regulators
- C. Place area to be cut over slag box
- D. Light torch
- E. Adjust to neutral flame
- F. Assume comfortable position
- G. Place hoses behind you
- H. Maneuver torch with both hands

JOB SHEET #4

I. Hold preheat flame with tip of inner cone 1/16" to 1/8" above edge of reinforcing bar until it becomes red

J. Depress the cutting lever and rotate torch tip into the direction of travel until rod is cut (Figure 1)

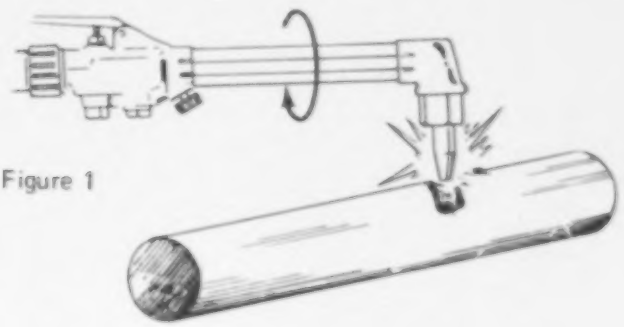


Figure 1

K. Repeat the procedure for each bar or rod

OXYACETYLENE CUTTING
UNIT II

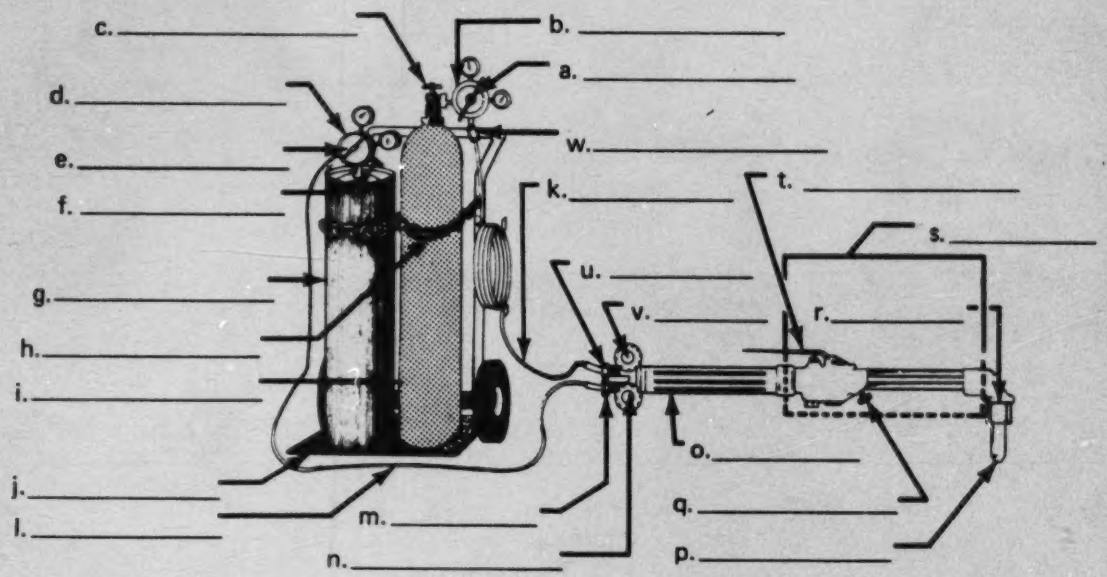
NAME _____

TEST

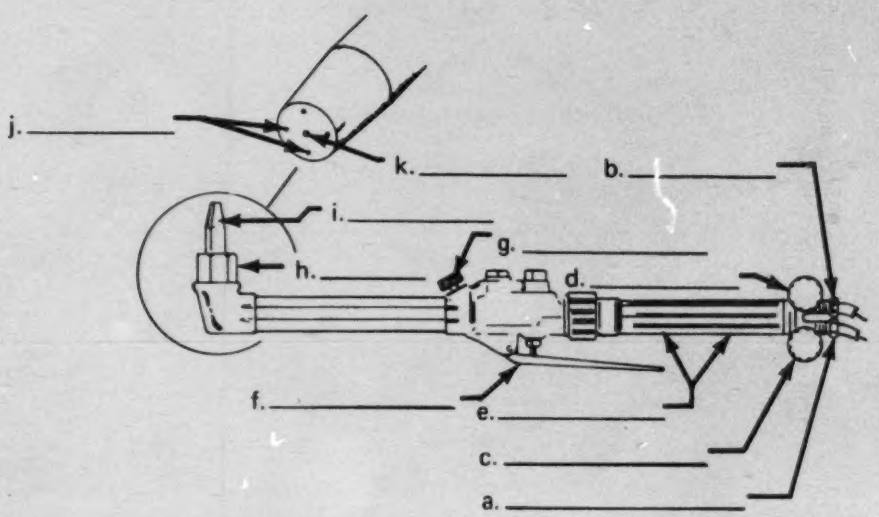
1. Match the terms on the right to the correct definitions.

_____a.	Fire inside of the torch	1.	Slag box
_____b.	Momentary burning back of the flame into the tip	2.	Oxidizing
_____c.	Process by which iron or steel is heated to a temperature where it can be rapidly oxidized by high purity oxygen flowing under pressure through a cutting torch	3.	Flashback
		4.	Dragline
		5.	Oxide
_____d.	Metal container with a layer of water or sand to catch hot slag	6.	Backfire
		7.	Kerf
_____e.	Situation in which the most distant portion of the cutting stream lags behind the stream nearest the cutting tip	8.	Purge
		9.	Flame cutting
_____f.	Combining oxygen with another substance	10.	Slag
_____g.	Substance that is produced when oxygen is combined with an element		
_____h.	Area of material removed from a piece of metal by a saw or cutting torch		
_____i.	To remove any foreign material from a system or component by flushing with the gas used in that system		
_____j.	Metal which melts away during the oxyacetylene cutting process		

2. Identify the parts of the oxyacetylene cutting outfit by writing the correct names in the blanks.



3. Identify the parts of the torch body and cutting attachment by writing the correct names in the blanks.



4. List eight rules for the safe handling of oxygen and acetylene equipment.

a.

b.

c.

d.

e.

f.

g.

h.

5. Identify the following three types of flames.

a. _____

b. _____

c. _____

6. List five reasons for poor cuts.

   a.

   b.

   c.

   d.

   e.

7. Select the causes of a backfire by placing an "X" in the appropriate blanks.

   _____a. Too much oxygen

   _____b. Insufficient acetylene or oxygen pressure

   _____c. Too much acetylene

   _____d. Loose cutting tip

   _____e. Overheating of cutting tip

   _____f. Bad "O" ring in torch body

   _____g. Dirty tip

8. Describe what happens when a backfire occurs.

9. Describe what happens when a flashback occurs.

10. List in the proper order the steps to follow in case of a flashback.

    a.

    b.

    c.

    d.

    e.

    f.

    g.

    h.

11. Demonstrate the ability to:

    a. Set up equipment for oxyacetylene cutting.

    b. Turn on, light, adjust to a neutral flame, and turn off oxyacetylene cutting equipment.

    c. Make ninety-degree cuts on mild steel and restart a cut.

    d. Cut round stock.

    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

OXYACETYLENE CUTTING
UNIT II

ANSWERS TO TEST

1. a. 3
   b. 6
   c. 9
   d. 1
   e. 4
   f. 2
   g. 5
   h. 7
   i. 8
   j. 10

2. a. Oxygen pressure regulating screw
   b. Oxygen regulator
   c. Oxygen cylinder valve
   d. Acetylene regulator
   e. Acetylene pressure regulating screw
   f. Acetylene cylinder valve
   g. Acetylene cylinder
   h. Safety chain
   i. Oxygen cylinder
   j. Cylinder truck
   k. Oxygen hose
   l. Acetylene hose
   m. Acetylene fitting
   n. Acetylene torch valve
   o. Torch body
   p. Tip
   q. Oxygen preheat valve
   r. Tip nut

s. Cutting attachment

t. Oxygen cutting lever

u. Oxygen fitting

v. Oxygen torch valve

3. a. Oxygen fitting

b. Acetylene fitting

c. Oxygen torch valve

d. Acetylene torch valve

e. Torch body

f. Oxygen cutting lever

g. Oxygen preheat valve

h. Tip nut

i. Tip

j. Preheat orifice

k. Cutting orifice

4. Any eight of the following:

a. Secure cylinders in an upright position to prevent damage to valves or regulators

b. Purge cylinder valve before attaching regulators

c. Release adjusting screws on regulator before opening cylinder valve

d. Stand to one side of regulator while slowly opening the cylinder valve

e. Do not use acetylene at pressures higher than 15 psi

f. Purge oxygen and acetylene passages before lighting torch

g. Light acetylene gas before opening oxygen valve on torch

h. Do not use oil on regulators, torches, fittings, or any place that it may come in contact with oxygen

i. Do not use oxygen as a substitute for compressed air

j. Keep heat, flames, and sparks away from combustibles

k. Use safety goggles, gloves, and protective clothing

l. Test connections for leaks with soapsuds and paintbrush

m. Do not use weld on containers that have been used for combustible materials

n. Avoid breathing toxic fumes when welding

o. Do not leave a burning torch unattended

p. Do not cut a weld near concrete

q. Operate torch in a well-ventilated place

r. Weld or cut at least five feet from cylinders

s. Protect hoses from hot metal, rupture, or mechanical damage

t. Others as added by instructor

5. a. Carburizing

b. Neutral

c. Oxidizing

6. Any five of the following:

a. Preheat flames too small

b. Preheat flames too long

c. Oxygen pressure too low

d. Oxygen pressure too high; nozzle size too small

e. Cutting speed too slow

f. Cutting speed too fast

g. Blowpipe travel unsteady

h. Cut lost and not carefully restarted

7. b, d, e, f, g

8. Description should include:
   a. Flame burns momentarily back into tip
   b. A loud snap or pop is emitted from the torch
   c. Flame either goes out or continues to burn in normal manner
9. Description should include:
   a. Flame disappears inside the torch body
   b. Squealing noise, smoke, and/or sparks are emitted from the torch tip
10. a. Close oxygen preheat valve
   b. Close oxygen torch valve
   c. Close acetylene torch valve
   d. Release oxygen regulator screw
   e. Release acetylene regulator screw
   f. Examine acetylene unit
   g. Reset regulator pressures
   h. Light torch
11. Performance skills evaluated to the satisfaction of the instructor

OXYACETYLENE FUSION WELDING
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to demonstrate the ability to light, adjust, and turn off the oxyacetylene welding equipment, handle the equipment properly, and make welds with or without filler rod. The student should also be able to select proper tip size and list factors that determine the correct type of filler rod to use. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with oxyacetylene fusion welding to the correct definitions.
2. Identify the parts of oxyacetylene fusion welding equipment.
3. Select factors that determine weld quality.
4. List properties of a good weld.
5. Select factors that determine tip size in oxyacetylene welding.
6. List two factors that determine the type of filler rod to use in oxyacetylene welding.
7. State the purpose of a filler rod.
8. Identify types of oxyacetylene fusion welding flames.
9. Demonstrate the ability to:
    a. Turn on, light, adjust, and turn off oxyacetylene welding equipment.
    b. Construct a corner weld without filler rod.
    c. Lay beads on gauge metal without filler rod.
    d. Lay beads on gauge metal with filler rod.
    e. Weld butt joints with filler rod.

OXYACETYLENE FUSION WELDING
UNIT III

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined in the job sheets.

G. Secure films on oxyacetylene fusion welding to show to the class.

H. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete job sheets.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Oxyacetylene Fusion Welding Equipment

2. TM 2--Welding Torches

3. TM 3--Welding Regulators

4. TM 4--Oxyacetylene Fusion Welding Flames

D. Job sheets

1. Job Sheet #1--Turn On, Light, Adjust, and Turn Off Oxyacetylene Welding Equipment

2. Job Sheet #2--Construct a Corner Weld Without a Filler Rod

3. Job Sheet #3--Lay Beads on Gauge Metal Without Filler Rod

4. Job Sheet #4--Lay Beads on Gauge Metal with Filler Rod

5. Job Sheet #5--Weld Butt Joints with Filler Rod

E. Test

F. Answers to test

II. References:

A. *Smith's Instructor's Manual for a Basic Course in Oxyacetylene Brazing, Cutting, and Welding.* Form 424. Minneapolis, Minnesota: Smith Welding Equipment Tescom Corporation.

B. *Smith's Instructor's Manual Answer Key.* Form 429. Minneapolis, Minnesota: Smith Welding Equipment/Division of Tescom Corp.

C. Phipps, Lloyd J.; McColly, H. F.; Scranton, L. L.; and Cook, G. C. *Farm Mechanics Text and Handbook.* Danville, Illinois: The Interstate Printers and Publishers, Inc.

D. Althouse, Andrew D.; Turnquist, Carl H.; and Bowditch, William A. *Modern Welding.* Homewood, Illinois: Goodheart-Willcox Co., Inc. 1965.

E. *The Oxyacetylene Handbook: A Manual on Oxyacetylene Welding and Cutting Procedures.* New York: Linde Division/Union Carbide Corp.

OXYACETYLENE FUSION WELDING
UNIT III

INFORMATION SHEET

I. Terms and definitions

A. Fusion welding--Joining of pieces of metal by heating the adjoining edges to the fusion or melting point and allowing them to flow or run together and then cool

B. Penetration--Distance from the original surface of the base metal to that point at which fusion ceases

C. Base metal--Metal to be welded

D. Alloy--Mixture with metallic properties; composed of two or more elements of which at least one is a metal

E. Inner cone--Inner white part of a neutral flame

F. Tack weld--Short weld used for temporarily holding metal in place

G. Backfire--Momentary burning back of the flame into the tip; flame goes out with a loud snap or pop

H. Flashback--Fire inside the torch; indicated by a hissing or squealing sound

(CAUTION: This is a very dangerous condition.)

II. Oxyacetylene fusion welding equipment (Transparencies 1, 2, and 3)

A. Acetylene cylinder

B. Acetylene cylinder valve

C. Acetylene fitting

D. Acetylene regulator

E. Oxygen cylinder

F. Oxygen cylinder valve

G. Oxygen fitting

H. Oxygen regulator

I. Oxygen torch valve

INFORMATION SHEET

J. Torch body

K. Acetylene torch valve

L. Welding tip

M. Welding goggles

N. Welding gloves

O. Safety chain

P. Flint lighter

Q. Cylinder truck

R. Oxygen hose

S. Acetylene hose

III. Factors that determine weld quality

A. Proper flame adjustment

B. Angle of tip

C. Distance from work

D. Speed of travel

E. Movement of tip

IV. Properties of a good weld

A. Consistent width

B. Straightness

C. Slightly crowned

D. Fused into base metal

E. Clean appearance

V. Factors that determine tip size

A. Thickness of metal

B. Size of welding rod

(NOTE: Always use manufacturer's recommendation on tip size.)

INFORMATION SHEET

VI. Factors that determine filler rod selection

A. Rod with similar properties as base metal

B. Thickness of metal

(NOTE: A general rule is to use a rod with a diameter equal to the thickness of the base metal.)

VII. Purpose of filler rod--To add strength to weld or joint

VIII. Oxyacetylene welding flames (Transparency 4)

A. Carburizing flame

(NOTE: The flame contains an excess of acetylene and is identified by an acetylene feather visible on the inner cone. It is recommended for welding cast iron. Carbon is introduced into the weld, causing hardening of the metal.)

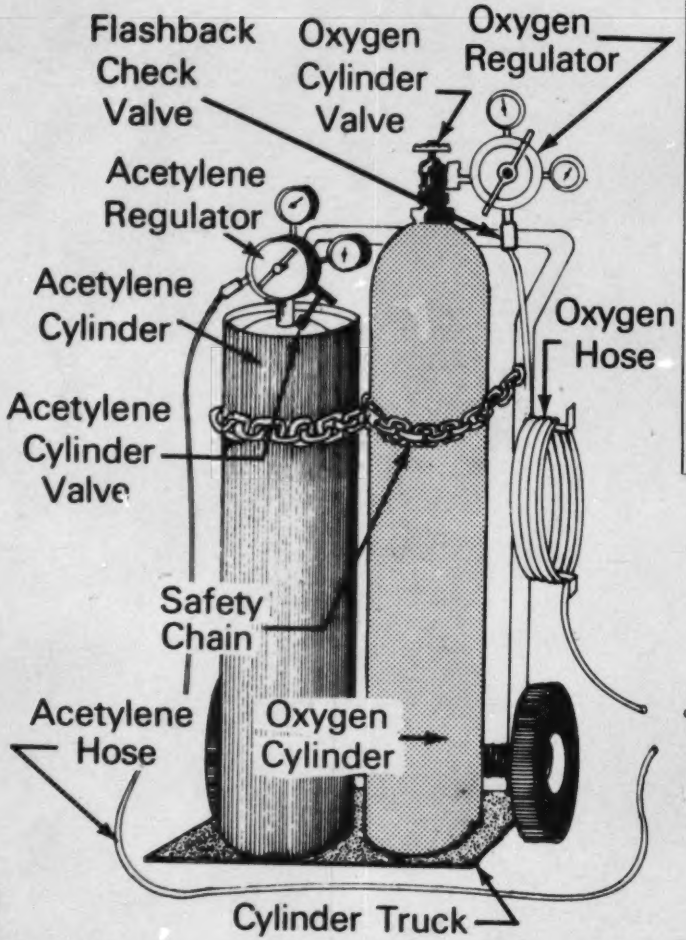
B. Neutral flame

(NOTE: The flame burns equal parts of oxygen and acetylene at a temperature of approximately 5950°F or 3270°C. It is identified by a clear well-defined white inner cone.)

C. Oxidizing flame

(NOTE: The flame burns an excess of oxygen and is identified by a short inner cone. It is the hottest of the three types of welding flames. It oxidizes the metal, causing it to harden and become brittle, and is therefore not recommended for welding most metals. It is recommended for brazing when slightly oxidized.)

Oxyacetylene Fusion Welding Equipment



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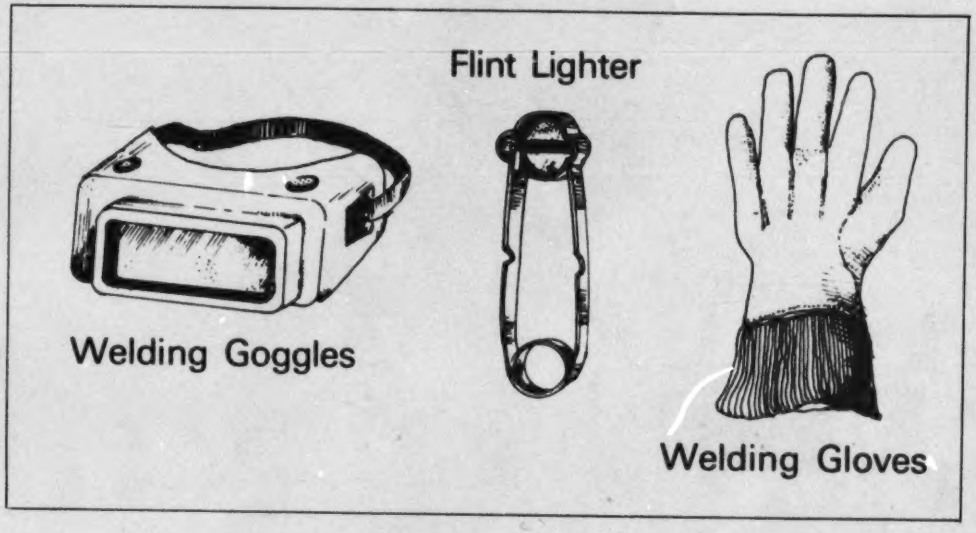

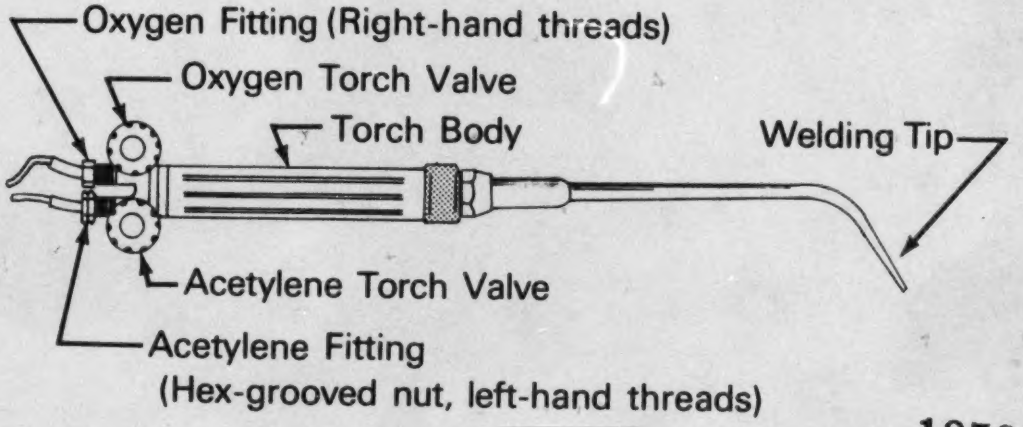

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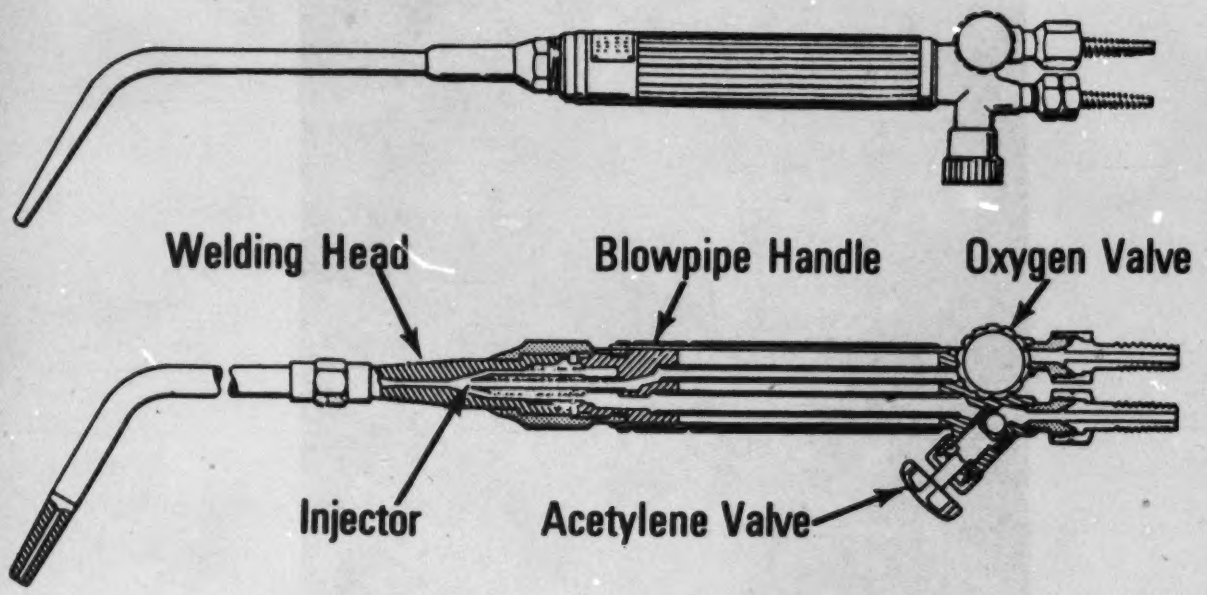
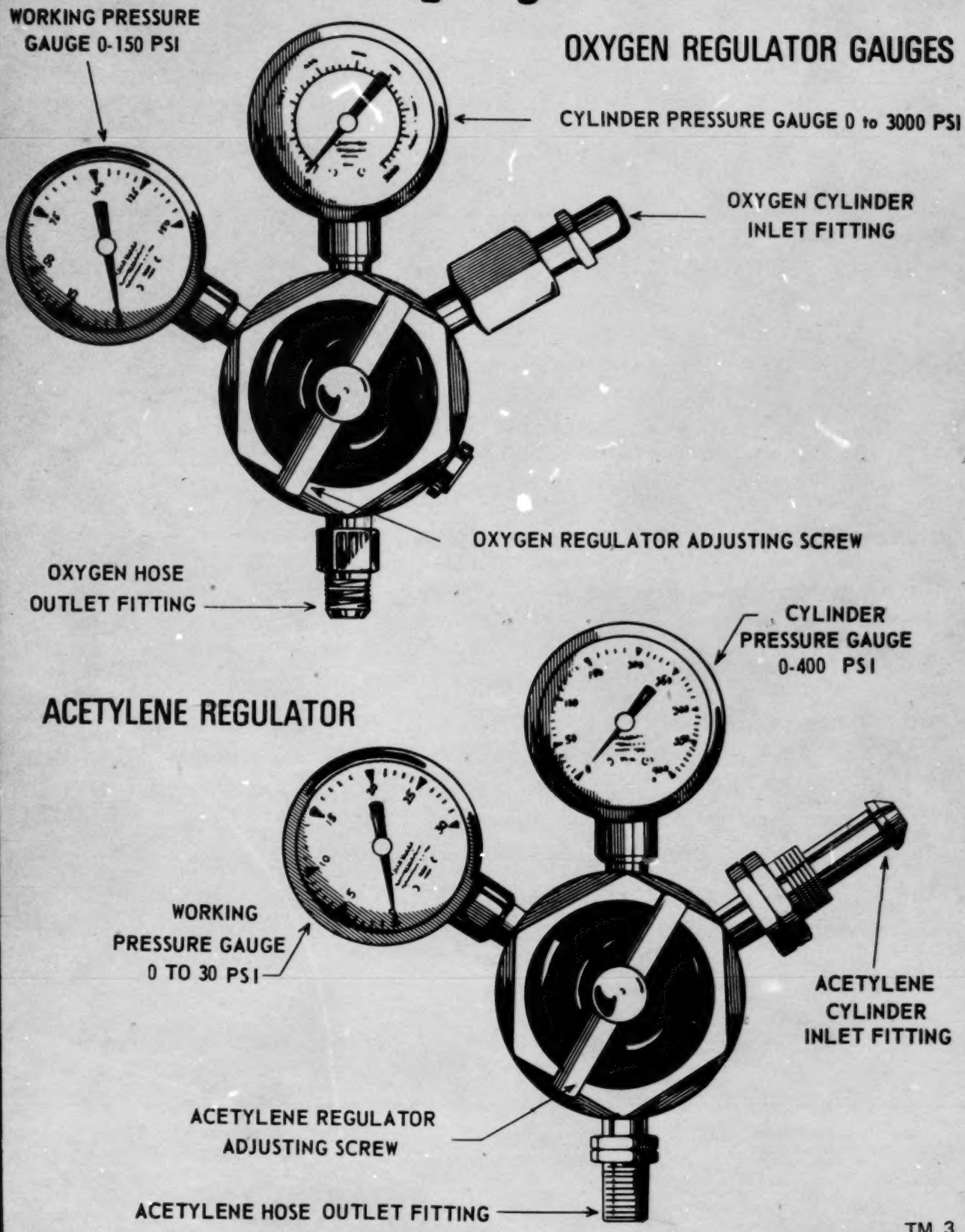
Welding Torches

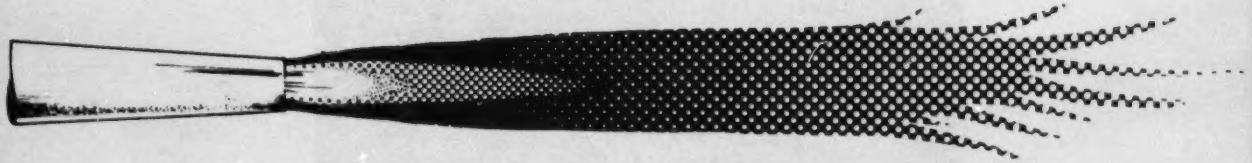


Welding Regulators


WORKING PRESSURE GAUGE 0-150 PSI
OXYGEN REGULATOR GAUGES
CYLINDER PRESSURE GAUGE 0 to 3000 PSI
OXYGEN CYLINDER INLET FITTING
OXYGEN REGULATOR ADJUSTING SCREW
OXYGEN HOSE OUTLET FITTING
CYLINDER PRESSURE GAUGE 0-400 PSI
ACETYLENE REGULATOR
WORKING PRESSURE GAUGE 0 TO 30 PSI
ACETYLENE CYLINDER INLET FITTING
ACETYLENE REGULATOR ADJUSTING SCREW
ACETYLENE HOSE OUTLET FITTING

TM 3

Oxyacetylene Fusion Welding Flames



Carburizing Flame

Neutral Flame

Oxidizing Flame

OXYACETYLENE FUSION WELDING
UNIT III

JOB SHEET #1--TURN ON, LIGHT, ADJUST, AND TURN OFF OXYACETYLENE WELDING EQUIPMENT

I. Tools and equipment

- A. Oxygen cylinder
- B. Acetylene cylinder
- C. Hoses
- D. Oxygen and acetylene regulators
- E. Torch body and welding tips
- F. Cylinder holder and hose rack
- G. Flint lighter
- H. Welding goggles with #5 lens
- I. Appropriate gloves

II. Procedure

A. Turn on and light torch

1. Check all cylinder, regulator, and torch valves to make sure they are turned off
2. Open acetylene cylinder valve 1/2 to 3/4 of a turn

   (CAUTION: Never open valve more than 1 1/2 turns.)
3. Open acetylene valve on torch one turn to purge line

   (CAUTION: Acetylene pressure should never exceed 15 psi.)
4. Turn acetylene regulator pressure adjusting screw clockwise until desired working pressure is reached

   (NOTE: The working pressure is determined by the size of the tip.)
5. Close acetylene valve on torch
6. Open oxygen cylinder valve all the way and tighten in open position

JOB SHEET #1

7. Open oxygen torch valve one turn

8. Turn oxygen regulator pressure adjusting screw clockwise until desired pressure is reached

   (NOTE: The working pressure is determined by the size of the tip.)

9. Close oxygen valve on torch

10. Open acetylene valve on torch 1/4 turn

11. Light the torch with flint lighter and adjust until smoke on flame clears

12. Open oxygen torch valve and adjust to a neutral flame with a tiny trace of feather on the inner cone

B. Adjust welding torch for the three types of flames, starting with a neutral flame

   (NOTE: To produce a carburizing flame, reduce the supply of oxygen by slowly closing the oxygen torch valve until an excess acetylene feather is produced. To produce an oxidizing flame, increase the supply of oxygen by slowly opening the oxygen torch valve until a short, white inner cone is produced.)

C. Turn off the torch and oxyacetylene welding unit

1. Close acetylene torch valve

2. Close oxygen torch valve

3. Close acetylene cylinder valve

4. Close oxygen cylinder valve

5. Open acetylene torch valve

   (NOTE: When gauges reach 0, release acetylene regulator pressure adjusting screw and close torch valve.)

6. Open oxygen valve on torch

   (NOTE: When gauges reach 0, release oxygen regulator pressure adjusting screw and close torch valve.)

   (CAUTION: Do not open the acetylene and oxygen torch valves at the same time.)

7. Place torch and hoses on hanger or brackets

OXYACETYLENE FUSION WELDING
UNIT III

JOB SHEET #2--CONSTRUCT A CORNER WELD WITHOUT A FILLER ROD

I. Tools and materials

A. Oxyacetylene welding unit

B. Welding tip (according to manufacturer's recommendations)

C. Gloves

D. Goggles

E. Pliers

F. Wire brush

G. Flint lighter

H. Firebrick

I. Mild steel, 2 strips of 16 gauge, 1 1/4" x 6"

II. Procedure

A. Prepare metal for welding

B. Place metal in welding position

C. Turn on oxyacetylene unit

D. Set working pressure

(NOTE: Refer to manufacturer's recommendations.)

E. Light torch and adjust to a neutral flame with very slight feather

F. Tack weld metal in position

G. Place inner cone about 1/16" to 1/8" from plate

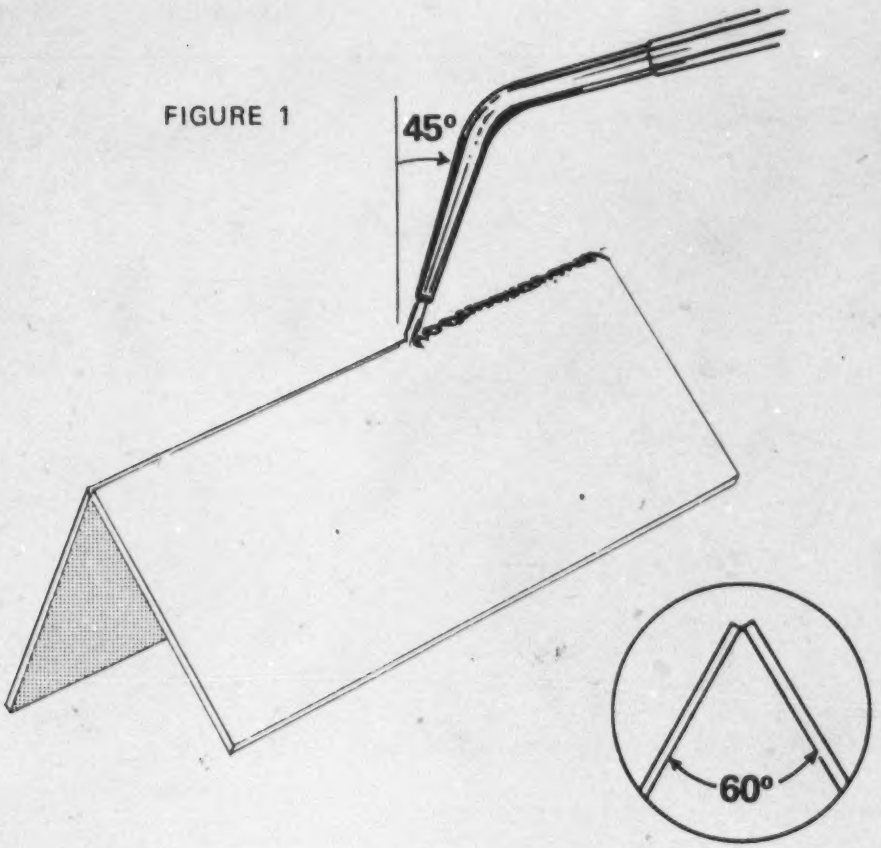
(NOTE: Do not begin travel until you have established a molten puddle.)

H. Begin welding at right end

JOB SHEET #2

I. Hold tip vertically at 45° angle from direction of travel (Figure 1)

FIGURE 1



J. Move flame slowly down the joint, forming a puddle as you travel from right to left

K. Examine welded joint for good bead characteristics and penetration

L. Show welded joint to instructor

OXYACETYLENE FUSION WELDING
UNIT III

JOB SHEET #3--LAY BEADS ON GAUGE METAL WITHOUT FILLER ROD

I. Tools and materials

- A. Oxyacetylene welding unit
- B. Welding tip (according to manufacturer's recommendations)
- C. Gloves
- D. Goggles
- E. Pliers
- F. Wire brush
- G. Flint lighter
- H. Firebrick
- I. Mild steel, 1 strip of 16 gauge, 1 1/4" x 6"

II. Procedure

- A. Prepare metal for welding
- B. Place metal in welding position
- C. Turn on oxyacetylene unit
- D. Set working pressure

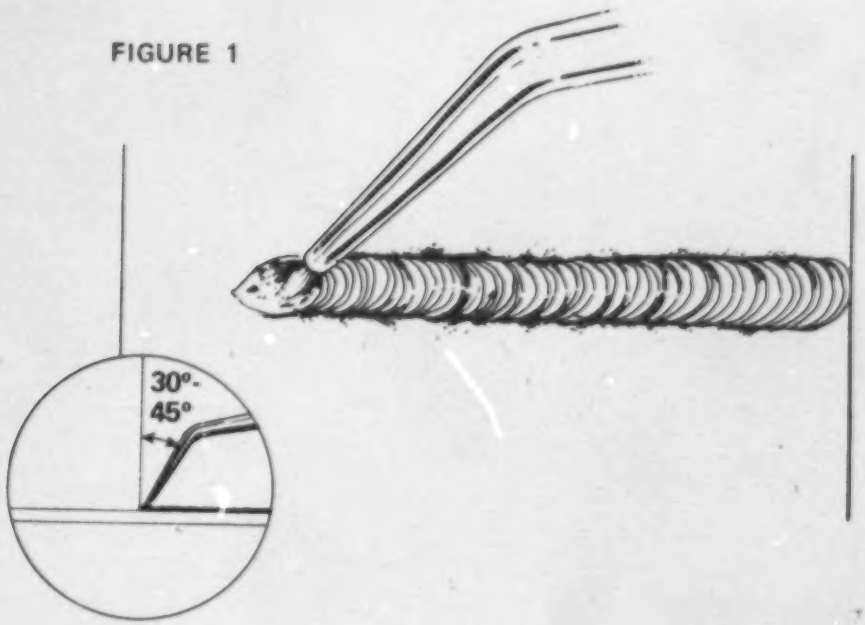
  (NOTE: Refer to manufacturer's recommendations.)
- E. Light torch and adjust to a neutral flame
- F. Place inner cone about 1/16" to 1/8" from metal

  (NOTE: Do not begin travel until you have established a molten puddle.)

JOB SHEET #3

G. Hold torch 30° to 45° from center in direction of travel (Figure 1)

FIGURE 1



H. Move the torch forward slowly, allowing the metal to melt

I. Show beads to instructor

OXYACETYLENE FUSION WELDING
UNIT III

JOB SHEET #4--LAY BEADS ON GAUGE METAL WITH FILLER ROD

I. Tools and materials

A. Oxyacetylene welding unit

B. Welding tip (according to manufacturer's recommendations)

C. Gloves

D. Goggles

E. Pliers

F. Wire brush

G. Flint lighter

H. Firebrick

I. Mild steel, 1 strip of 16 gauge, 1 1/4" x 6"

J. Mild steel filler rod (according to manufacturer's recommendations)

II. Procedure

A. Prepare metal for welding

B. Place metal in welding position

C. Turn on oxyacetylene unit

D. Set working pressure

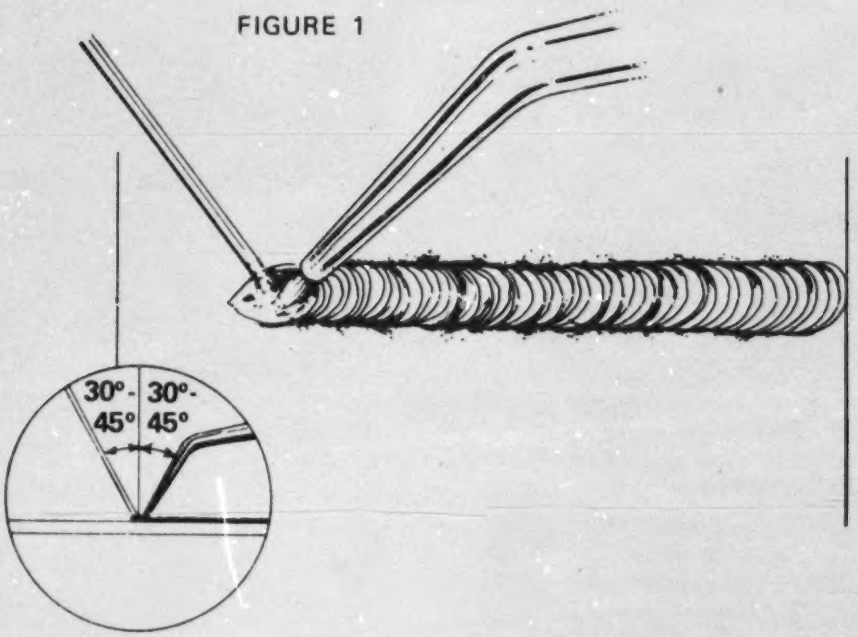
(NOTE: Refer to manufacturer's recommendations.)

E. Light torch and adjust to a neutral flame

JOB SHEET #4

F. Hold torch 30° to 45° from center (Figure 1)

FIGURE 1



G. Place inner cone about 1/16" to 1/8" from surface of puddle

(NOTE: Do not begin travel until you have established a molten puddle.)

H. Add filler rod to front edge of puddle in front of torch

I. Move puddle forward with torch and allow puddle to form in base metal

J. Add rod to front edge of puddle and withdraw rod as you move puddle forward

K. Keep puddle the same size and shape for the entire length of the bead

L. Show bead to instructor when completed

OXYACETYLENE FUSION WELDING
UNIT III

JOB SHEET #5--WELD BUTT JOINTS WITH FILLER ROD

I. Tools and materials

A. Oxyacetylene welding unit

B. Welding tip (according to manufacturer's recommendations)

C. Gloves

D. Goggles

E. Pliers

F. Wire brush

G. Flint lighter

H. Firebrick

I. Mild steel, 2 strips of 16 gauge, 1 1/4" x 6"

J. Mild steel filler rod (according to manufacturer's recommendations)

II. Procedure

A. Prepare metal for welding

B. Place metal in welding position

C. Turn on oxyacetylene unit

D. Set working pressure

(NOTE: Refer to manufacturer's recommendations.)

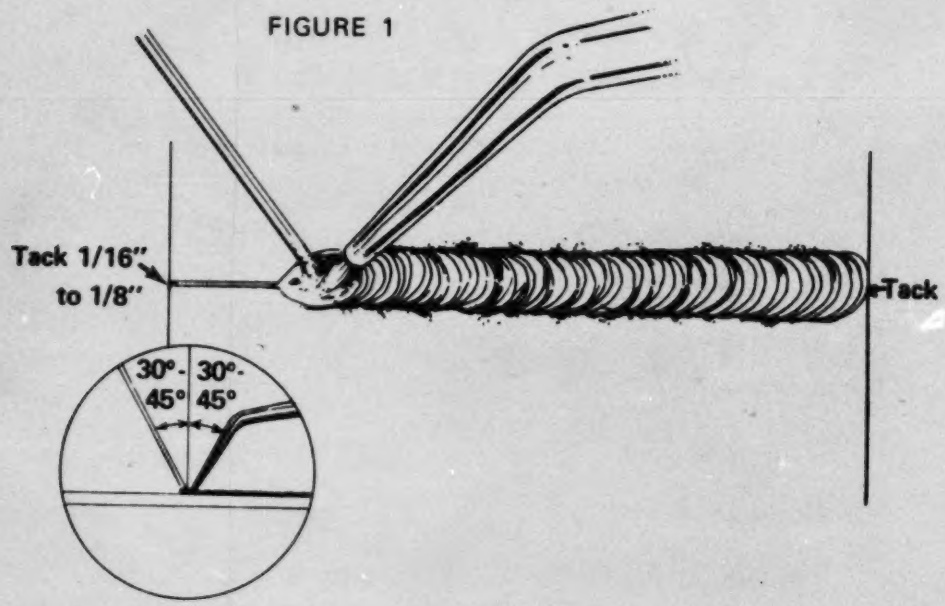
E. Light torch and adjust to a neutral flame

F. Tack weld metal together at both ends of joint

JOB SHEET #5

G. Hold torch 30° to 45° from center (Figure 1)

FIGURE 1



(NOTE: Do not begin travel until you have established a molten puddle.)

H. Place inner cone about 1/16" to 1/8" from surface of puddle

I. Add filler rod to front edge of puddle in front of torch

J. Move puddle forward with torch and allow puddle to form in base metal

K. Add rod to front edge of puddle and withdraw rod as you move puddle forward

L. Keep puddle the same size and shape for the entire length of the bead

M. Show bead to instructor

OXYACETYLENE FUSION WELDING
UNIT III

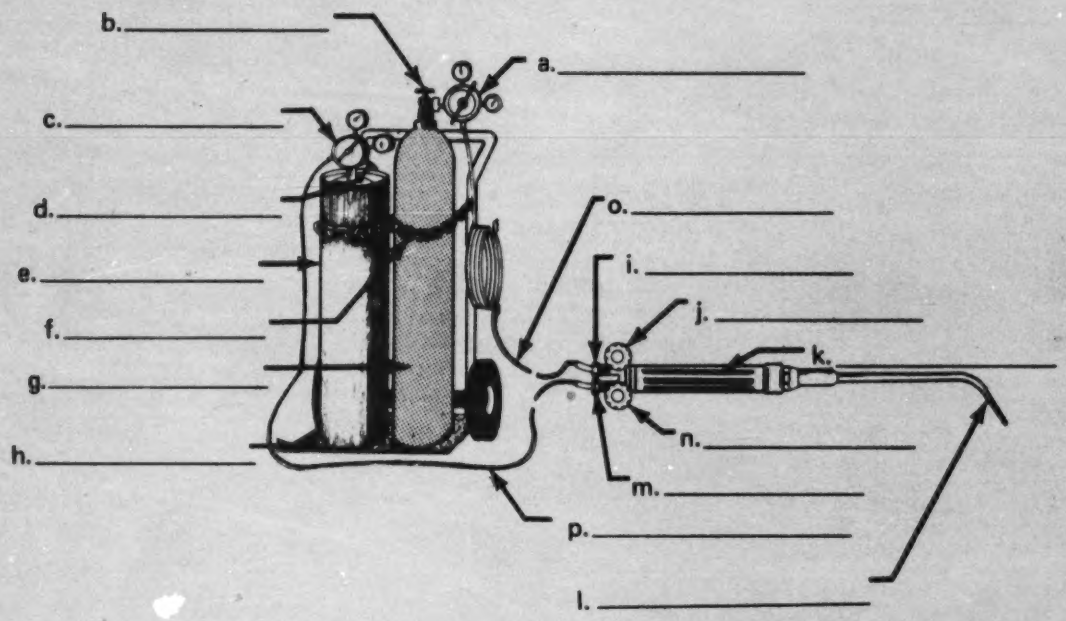
NAME _____

TEST

1. Match the terms on the right to the correct definitions.

_____a. Metal to be welded	1. Tack weld
_____b. Fire inside the torch; indicated by a hissing or squealing sound	2. Flashback
_____c. Joining of pieces of metal by heating the adjoining edges to the fusion or melting point and allowing them to flow or run together and then cool	3. Backfire
_____d. Inner white part of a neutral flame	4. Inner cone
_____e. Distance from the original surface of the base metal to that point at which fusion ceases	5. Alloy
_____f. Short weld used for temporarily holding metal in place	6. Base metal
_____g. Mixture with metallic properties; composed of two or more elements of which at least one is a metal	7. Penetration
_____h. Momentary burning back of the flame into the tip; flame goes out with a loud snap or pop	8. Fusion welding

2. Identify the parts of the oxyacetylene fusion welding equipment illustrated below by writing the correct names in the blanks.



q. _____

r. _____

s. _____

3. Select factors that determine weld quality by placing an "X" in the appropriate blanks.

_____a. Proper flame adjustment

_____b. Angle of tip

_____c. Distance from work

_____d. Thickness of metal

_____e. Speed of travel

_____f. Movement of tip

_____g. Width of bead

4. List three properties of a good weld.

a.

b.

c.

5. Select factors that determine tip size by placing an "X" in the appropriate blanks.

_____a. Size of welding rod

_____b. Temperature of metal

_____c. Thickness of metal

_____d. Distance to work

6. List two factors that determine the type of filler rod to use in oxyacetylene welding.

a.

b.

7. State the purpose of a filler rod.

8. Identify the three types of flames illustrated below by writing the correct names in the blanks.

a. _____

b. _____

c. _____

9. Demonstrate the ability to:

   a. Turn on, light, adjust, and turn off oxyacetylene welding equipment.

   b. Construct a corner weld without filler rod.

   c. Lay beads on gauge metal without filler rod.

   d. Lay beads on gauge metal with filler rod.

   e. Weld butt joints with filler rod.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

OXYACETYLENE FUSION WELDING
UNIT III

ANSWERS TO TEST

1. a. 6
   b. 2
   c. 8
   d. 4
   e. 7
   f. 1
   g. 5
   h. 3

2. a. Oxygen regulator
   b. Oxygen cylinder valve
   c. Acetylene regulator
   d. Acetylene cylinder valve
   e. Acetylene cylinder
   f. Safety chain
   g. Oxygen cylinder
   h. Cylinder truck
   i. Oxygen fitting
   j. Oxygen torch valve
   k. Torch body
   l. Welding tip
   m. Acetylene fitting
   n. Acetylene torch valve
   o. Oxygen hose
   p. Acetylene hose
   q. Welding goggles
   r. Flint lighter
   s. Welding gloves

3. a, b, c, e, f

4. Any three of the following:

   a. Consistent width

   b. Straightness

   c. Slightly crowned

   d. Fused into base metal

   e. Clean appearance

5. a, c

6. a. Rod with similar properties as base metal

   b. Thickness of metal

7. To add strength to weld or joint

8. a. Carburizing

   b. Oxidizing

   c. Neutral

9. Performance skills evaluated to the satisfaction of the instructor

OXYACETYLENE BRAZE WELDING
UNIT IV

UNIT OBJECTIVE

After completion of this unit, the student should be able to describe the differences between braze welding and fusion welding and list advantages and disadvantages of braze welding. The student should also be able to describe the reaction when adding bronze to base metal that is too hot, too cold, or of correct temperature. This knowledge will be evidenced through demonstration and by scoring eighty-five percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with brazing to the correct definitions.
2. List advantages and disadvantages of braze welding.
3. State the importance of having a chemically clean metal surface in braze welding.
4. Select methods for removing oxides from a clean metal surface.
5. Describe the differences between braze welding and fusion welding.
6. List purposes for using flux.
7. Describe the reaction of molten bronze when the temperature of the base metal is too hot, too cool, and correct.
8. Demonstrate the ability to braze weld a square groove butt joint.

OXYACETYLENE BRAZE WELDING
UNIT IV

SUGGESTED ACTIVITIES

I. Instructor:

A. Provide student with objective sheet.

B. Provide student with information and job sheets.

C. Make transparency.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedure outlined in the job sheet.

(NOTE: The instructor may want to secure the film on braze welding from a local welding supplier to show to the class.)

G. Give test.

II. Student:

A. Read objective sheet.

B. Study information sheet.

C. Complete job sheet.

D. Take test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency master: TM 1--Braze Welding a Butt Joint

D. Job Sheet #1--Braze Weld a Square Groove Butt Joint

E. Test

F. Answers to test

II. References:

A. *The Oxyacetylene Handbook: A Manual on Oxyacetylene Welding and Cutting Procedures.* New York: Linde Div./ Union Carbide Corp., 1960.

B. Althouse, Andrew D.; Turnquist, Carl H.; and Bowditch, William A. *Modern Welding.* Homewood, Illinois: Goodheart-Willcox Co., Inc., 1965.

C. Giachino, J. W.; Weeks, William; and Brune, Elmer. *Welding Skills and Practices.* Chicago: American Technical Society, 1967.

OXYACETYLENE BRAZE WELDING
UNIT IV

INFORMATION SHEET

I. Terms and definitions

A. Braze welding--Heating the base metal to a dull red color and depositing a bead over the seam (joint) with a bronze filler rod; the base metal is not melted (Transparency 1)

B. Malleability--Property of metals which allows them to be bent or permanently distorted without rupture; opposite of brittleness

C. Ductile--Capable of being drawn or stretched out

D. Tinning operation--Melting a small amount of bronze rod onto the surface and allowing it to spread along the entire seam (joint)

(NOTE: It is this flow of the thin film of bronze which is known as *tinning.*)

E. Flux--Chemical used to clean metals and to promote fusion during the welding process

II. Advantages and disadvantages of braze welding

A. Advantages

1. Provides less chance of destroying main characteristics of base metal since it is not heated to a molten condition

2. Consumes less gas

3. Can be used on thin metals

4. Used on malleable castings

5. Increases speed of joining metals

6. May be used to join different kinds of metals

B. Disadvantages

1. Cannot be used on metal where stress is a factor

2. Expensive to use

INFORMATION SHEET

3. Not recommended for parts which are raised to temperatures higher than the melting point of bronze, either in service or during heat treatment

   (NOTE: Bronze will lose its strength at temperatures above 500°F or 260°C.)

4. Will not bond unless base metal has corrosion-resistant properties similar to bronze

III. Importance of a chemically clean surface in braze welding

A. Ensures that the molten bronze will stick to the base metal

B. Has a stronger bond on base metal

C. Allows bronze to flow smoothly and evenly over entire weld area

IV. Methods for removing oxides from clean metal surface

A. Mechanical means

1. Wire brush

2. Grinder

B. Chemical means--Flux

(NOTE: Both methods should be used to completely remove the oxides.)

V. Differences between braze welding and fusion welding

A. Braze welding

1. The base metal is not melted

   (NOTE: The base metal is heated only to a dull red color.)

2. An alloy rod is used to lay a thin coat of bronze along the seam

B. Fusion welding

1. Base metal is melted and joined

2. Rod with similar characteristics of base metal must be used

INFORMATION SHEET

VI. Purposes for using flux

A. Clean the base metal chemically

B. Prevent oxidation of filler metal

C. Float and remove oxides already present

D. Increase flow of filler metal

E. Increase ability of filler metal to adhere to the base metal

F. Bring the filler metal into immediate contact with metals being joined

G. Permit the filler metal to penetrate the pores of the base metal

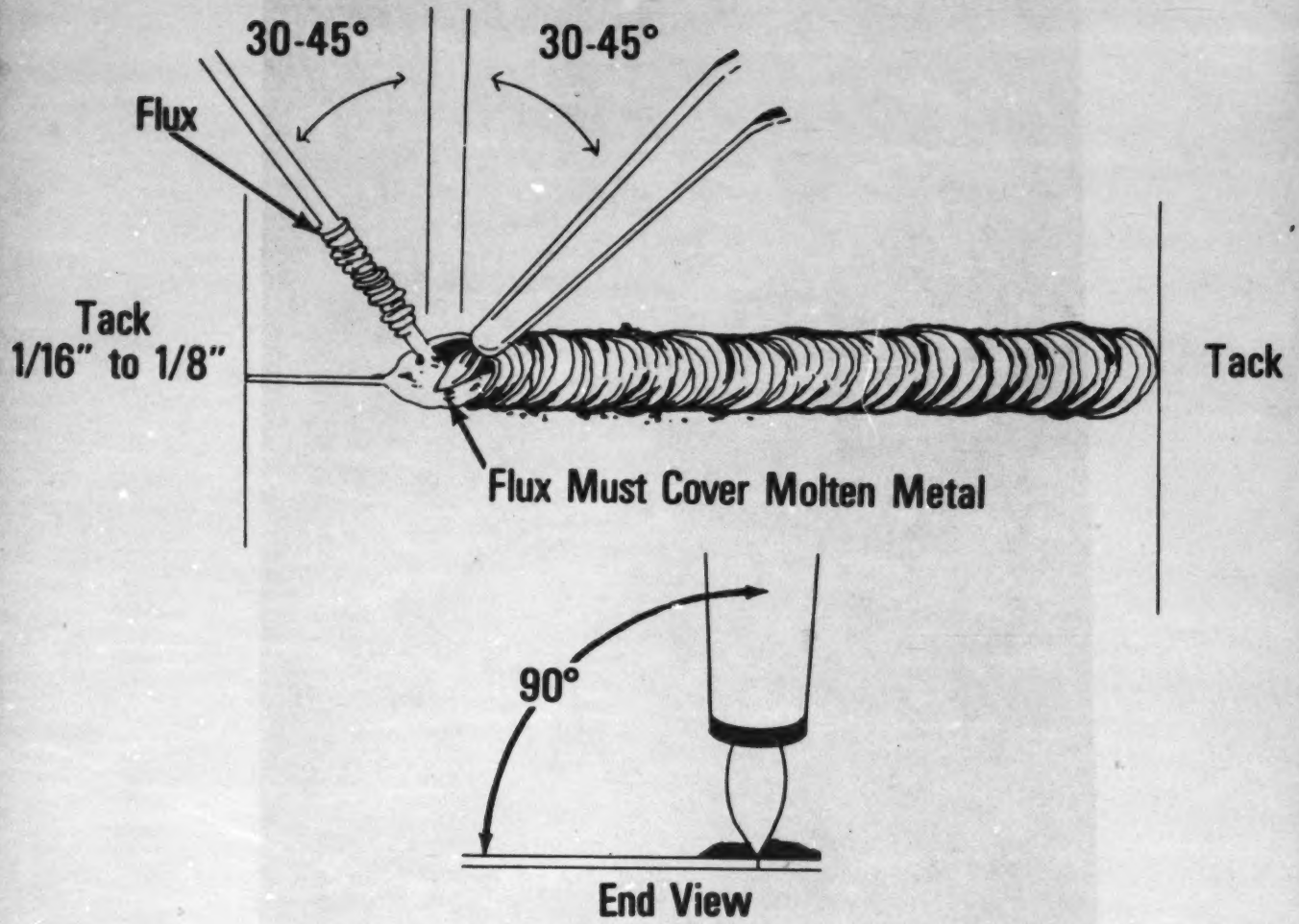
VII. Reaction of molten bronze at different temperatures

A. Too hot--The molten bronze will tend to boil and form little balls

B. Too cool--The molten bronze will form into drops rather than flowing evenly over the surface

C. Correct--The molten bronze will spread evenly and flow over a considerable area

Braze Welding A Butt Joint



OXYACETYLENE BRAZE WELDING
UNIT IV

JOB SHEET #1--BRAZE WELD A SQUARE GROOVE BUTT JOINT

I. Tools and materials

- A. Oxyacetylene welding unit
- B. Appropriate gloves
- C. Safety glasses
- D. Goggles with No. 5 lenses
- E. Welding tip (according to manufacturer's recommendations)
- F. Wire brush
- G. Flint lighter
- H. Firebrick
- I. Mild steel, 2 strips of 1/8" thick and 1 1/4" x 6"
- J. Bronze filler rod (according to manufacturer's recommendations)
- K. Welding flux
- L. Acetylene valve wrench

II. Procedure

- A. Clean metal
- B. Place metal in brazing position, 1/16" to 1/8" apart
- C. Turn on oxyacetylene unit
- D. Adjust proper working pressure of oxygen and acetylene

  (NOTE: Use manufacturer's recommendations.)
- E. Place metal on firebrick

  (NOTE: Do not lay metal flat on brick. Arrange metal so a small space will be between the base metal and the firebrick.)
- F. Light and adjust torch to a neutral or slightly oxidizing flame

JOB SHEET #1

G. Preheat the end of the brazing rod and dip in the flux or use fluxed rod

H. Tack metal in place using braze filler metal

I. Heat the surface of the weld area slightly

J. Hold torch 30° to 45° vertically; hold filler rod at same angle in opposite direction (Figure 1)

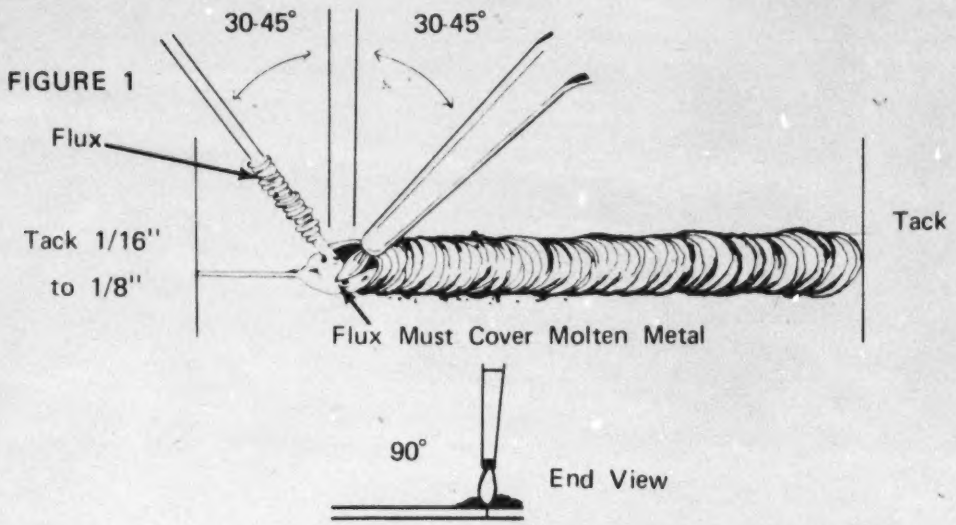


FIGURE 1

K. Melt a small amount of bronze rod onto the surface and allow it to spread along the entire seam when a cherry red color occurs

L. Start depositing the proper size bead when the base metal is tinned sufficiently

(NOTE: When metal is not hot enough, the bronze will form into drops; when metal is too hot, bronze tends to boil.)

M. Complete the weld

N. Have instructor inspect weld

O. Practice doing other welds

OXYACETYLENE BRAZE WELDING
UNIT IV

NAME _____

TEST

1. Match the terms on the right to the correct definitions.

_____a.	Capable of being drawn or stretched out	1. Flux
_____b.	Chemical used to clean metals and to promote fusion during the welding process	2. Braze welding
_____c.	Property of metals which allows them to be bent or permanently distorted without rupture; opposite of brittleness	3. Malleability
_____d.	Heating the base metal to a dull red color and depositing a bead over the seam (joint) with a bronze filler rod; the base metal is not melted	4. Tinning operation
_____e.	Melting a small amount of bronze rod onto the surface and allowing it to spread along the entire seam (joint)	5. Ductile

2. List three advantages and three disadvantages of braze welding.

a. Advantages

1)

2)

3)

b. Disadvantages

1)

2)

3)

3. State the importance of having a chemically clean metal surface in braze welding.

4. Select methods for removing oxides from a clean metal surface by placing an "X" in the appropriate blanks.

_____a. Wire brush

_____b. Hammer

_____c. Acid

_____d. Grinder

_____e. Flux

_____f. Water

5. Describe the differences between braze welding and fusion welding.

a. Braze welding

b. Fusion welding

6. List five purposes for using flux.

a.

b.

c.

d.

e.

7. Describe the reactions of molten bronze when the temperature of the base metal is:

   a. Too hot

   b. Too cool

   c. Correct

8. Demonstrate the ability to braze weld a square groove butt joint.

   (NOTE: If this activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

OXYACETYLENE BRAZE WELDING
UNIT IV

ANSWERS TO TEST

1. a. 5
   b. 1
   c. 3
   d. 2
   e. 4

2. Any three from each group:
   a. Advantages
      1) Provides less chance of destroying main characteristics of base metal since it is not heated to a molten condition
      2) Consumes less gas
      3) Can be used on thin metals
      4) Used on malleable castings
      5) Increases speed of joining metals
      6) May be used to join different kinds of metals
   b. Disadvantages
      1) Cannot be used on metal where stress is a factor
      2) Expensive to use
      3) Not recommended for parts which are raised to temperatures higher than the melting point of bronze, either in service or during heat treatment
      4) Will not bond unless base metal has corrosion-resistant properties similar to bronze

3. a. Ensures that the molten bronze will stick to the base metal
   b. Has a stronger bond on base metal
   c. Allows bronze to flow smoothly and evenly over entire weld area

4. a, d, e

5. Description should include:

   a. Braze welding

      1) The base metal is not melted

      2) An alloy rod is used to lay a thin coat of bronze along the seam

   b. Fusion welding

      1) Base metal is melted and joined

      2) Rod with similar characteristics of base metal must be used

6. Any five of the following:

   a. Clean the base metal chemically

   b. Prevent oxidation of filler metal

   c. Float and remove oxides already present

   d. Increase flow of filler metal

   e. Increase ability of filler metal to adhere to the base metal

   f. Bring the filler metal into immediate contact with metals being joined

   g. Permit the filler metal to penetrate the pores of the base metal

7. Description should include:

   a. Too hot--The molten bronze will tend to boil and form little balls

   b. Too cool--The molten bronze will form into drops rather than flowing evenly over the surface

   c. Correct--The molten bronze will spread evenly and flow over a considerable area

8. Performance skills evaluated to the satisfaction of the instructor